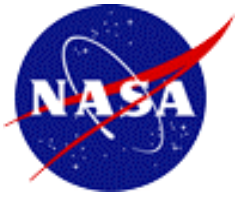
FINAL

PROTECTED SPECIES MANAGEMENT STRATEGY FOR NASA GLENN RESEARCH CENTER AT LEWIS FIELD AND PLUM BROOK STATION

VOLUME III: MANAGEMENT PLAN

Prepared for:



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ACRONYMS AND ABBREVIATIONS

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
ESA	Endangered Species Act of 1973
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
GRC	Glenn Research Center
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NWI	National Wetlands Inventory
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
PBS	Plum Brook Station
SAIC	Science Applications International Corporation
USDA	United States Department of Agriculture
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geographic Service

1. INTRODUCTION

This report was prepared by Science Applications International Corporation (SAIC) to assist the National Aeronautics and Space Administration (NASA) in preparing a protected species management strategy. The report presents recommendations and general methodologies for managing protected species and rare plant communities at Lewis Field and Plum Brook Station (PBS). NASA facilities are required to maintain current records of species protected by the Endangered Species Act (ESA). In addition, NASA facilities must develop programs for the management of any protected species and their critical habitat where present on property managed by NASA. It is the policy of NASA GRC to comply with all applicable federal and state regulations with regards to endangered and threatened species. To facilitate GRC's compliance with the ESA and NASA policies, SAIC proposed a strategy for the identification and management of protected species at the Lewis Field and PBS facilities. The strategy consists of three interrelated tasks:

1) Perform biological surveys at Lewis Field and PBS to provide current records of protected species at these facilities.
2) Develop geographic information system (GIS) data layers identifying the terrestrial plant communities and aquatic habitats at the two facilities and incorporating locations of protected species identified during the surveys.
3) Produce a management plan for the protected species that utilizes the GIS as a management tool.

The goal of this strategy is to produce a management plan that contains current information on protected species and rare plant communities that will facilitate prioritization, planning, and implementation of specific management activities. The GIS data layers containing the current information are easily updated and will be integrated with other spatial data critical to the management of the facilities. The GIS data layers will become a component of the facility GISs developed by the Stennis Space Center.

The three components of the management strategy are presented in three reports, *Protected Species Management Plan, Volumes I - III*. Volume I: Biological Surveys (ODNR 2002) was prepared by the Ohio Department of Natural Resources under contract to SAIC. Volume I corresponds to component one of the strategy. Volume II: Plant Community Survey was prepared by SAIC and corresponds to component two of the strategy. Volume II is the companion text to the electronic GIS data layers developed for this project. This report is Volume III: Management Plan, which integrates the results of Volumes I and II to present management strategies for protected species and important plant communities at PBS and Lewis Field.

Two general approaches to natural resource management are presented. The first is a more holistic approach where management of entire plant communities is recommended. The second is a focused approach where management of individual species or groups of species requires additional activities not covered by the first approach. The combination of these approaches will ensure the preservation of protected species as well as the preservation and enhancement of natural plant communities at the two facilities.

1.1 Project Description for the Management Plan

A single management plan has been prepared to present and discuss methods for managing the protected species identified at the Lewis Field and PBS. The plan incorporates recommendations from the biological survey report (Task 1) and plant community/aquatic resource information generated during Task 2. The plan addresses habitat requirements, methods for conserving and/or improving habitat, specific biological threats to protected species (e.g., invasive plants, browsing by deer, etc.), and other management issues. The plan also discusses methods for utilizing the GIS to support species management.

Management of protected species by NASA is required by the ESA and it is NASA policy to comply with other state regulations. Therefore, these laws are briefly discussed to provide the context for why management is required. General stewardship of natural resources is not specifically codified, but it is consistent with natural resource laws and the policies of federal agencies. Therefore, management techniques such as restoration of native plant communities are discussed so that resource managers utilizing this document will see the complete range of activities that may be implemented to enhance the natural resources they manage.

PBS is far larger than Lewis Field and it contains many more rare species and important plant communities. Therefore, investigation and documentation of protected species and rare plant communities at PBS required significantly more effort. In this report, the greater importance of natural resources at PBS is reflected by more detailed discussions of areas containing rare species or rare plant communities and greater discussion of management recommendations. In addition, the management recommendations for PBS are presented first.

1.2 Site Locations and Descriptions

1.2.1 Lewis Field

Introduction to NASA Glenn Research Center at Lewis Field

The GRC at Lewis Field in Cleveland, OH was established in 1941 as the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics (NACA). In 1958, NACA was reorganized into NASA and the laboratory became part of the new organization. On-site technical and support facilities have expanded continuously throughout the years and the campus-like setting now includes a diverse array of laboratories, office buildings, research and test stations, and support facilities.

Size and Location

At its Cleveland site, NASA owns or leases 147.62 hectares (364.49 acres) (LeRC 1995). The site is located in western Cuyahoga County, Ohio and is predominantly within the city limits of Brookpark, approximately twenty miles southwest of downtown. A small part of the site to the north is located in the city of Fairview Park. The site borders the Cleveland Hopkins International Airport to the east. To the north and west is the Rocky River Reservation, a part of the Cleveland Metropolitan

Park District (Metroparks). The southern boundary of the site is adjacent to residential and business districts of the city of Brook Park, including the Tech Park office development.

The site lies between latitudes 41°24' and 41°25'30"N, and longitudes 81°51' and 81°53"W. The location can be found on the United States Geological Survey (USGS) 7.5 minute-series topographic map for the Lakewood Quadrangle (41081-D7-TF-024).

Site Facilities

The GRC site is organized administratively into four geographic areas. The North Area is the land north of Brookpark Road. This contains two administrative buildings and a parking lot. This area is within the city of Fairview Park. The Central Area is the largest portion and contains the greatest concentration of buildings and many of the major test facilities. The Central Area contains specialized facilities which supply altitude exhaust, compressed air, and cooling water. These systems are essential to a number of test operations and therefore combustion-related experiments are normally clustered here. The Central Area is bordered by Brookpark Road to the north, the Airport to the east, and Cedar Point Road to the south.

The South Area contains the Rocket Engine Test Facility, the Central Chemical Storage Facility, bulk storage areas, and other facilities requiring a buffer zone. The South Area is the portion of the site south of Cedar Point Road. The West Area is separated from the Central Area by Abram Creek and includes the Management Conference Building, recreational areas, the day care center, and other facilities.

The 1995 *Real Property Report* (LeRC 1995) lists 176 buildings, structures, and other entities at Lewis Field including many specialized Research and Development (R&D) facilities. Lewis Field boasts many unique test facilities for conducting wind tunnel, aeronautics, propulsion, space power, and advanced research.

1.2.2 Plum Brook Station (PBS)

Introduction to NASA Glenn Research Center at Plum Brook Station

The PBS is operated as a satellite facility (component installation) of the NASA Glenn Research Center. Use of this site by the Federal Government began in 1941 when the U.S. Army established the Plum Brook Ordnance Works for the manufacture of munitions. Munitions production took place from 1941 to 1945, after which buildings and production lines were decontaminated and decommissioned. There were then several changes in ownership and eventual transfer of portions of the site to NACA (later NASA) in 1955.

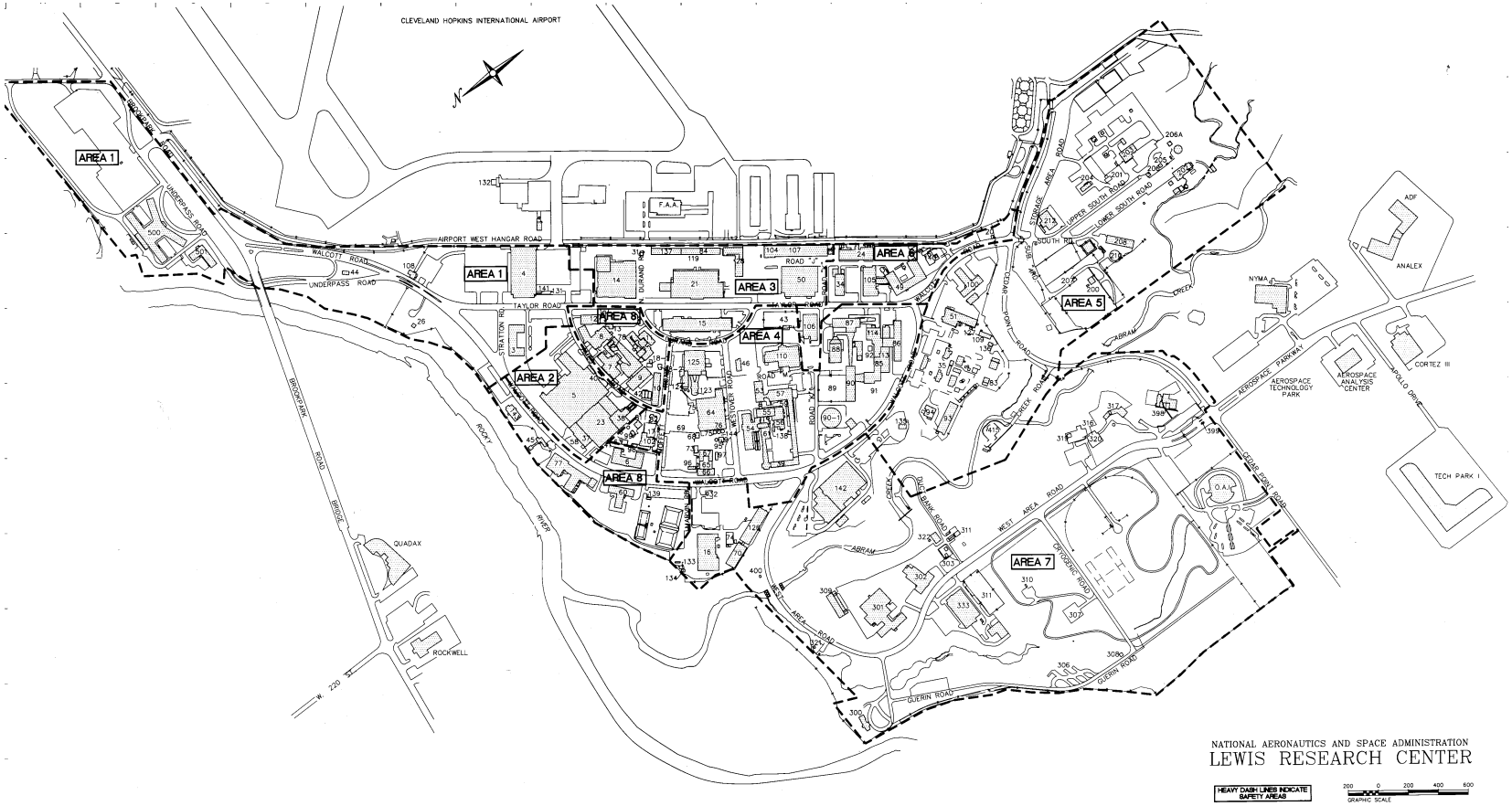

FIGURE 1
MAP OF LEWIS FIELD

NACA's original interest in the site was as a testing location for high-energy rocket engines and nuclear power systems. Other activities at PBS over the years have included the development of special pumps for space applications, rocket engine research, space vehicle testing, cryogenic testing, wind tunnel testing, and related aerospace research.

Size and Location

The NASA portion of the PBS site is 2,614 hectares (6,454 acres) in size (LeRC 1995). The site is located in a rural area in west central Erie County, Ohio, approximately 80 kilometers (50 miles) west of the GRC facility in Cleveland. The nearest large city is Sandusky, 6 kilometers (4 miles) to the north. Most of the PBS site is in Perkins and Oxford townships, with some land in Huron and Milan townships to the east. The site boundaries are Bogart Road to the north, Mason Road to the south, U.S. Highway 250 to the east, and County Road 43 to the west (Figure 2).

The northernmost point is at latitude 41°23'39"N; and the southernmost point at 41°20'04"N. The westernmost point is at longitude 82°43'12"W; and the easternmost point is at 82°38'39"W. The location can be found on the USGS 7.5 minute-series topographic maps for the Kimball and Sandusky Quadrangles (N4115-W8237.5/7.5 and 41082-D6-TF-024, respectively).

Site Facilities

The 1995 *Real Property Report* (LeRC 1995) lists 179 buildings, structures, and other entities at PBS. These include offices, mechanical and process equipment areas, test facilities, substations, and wastewater treatment facilities.

The PBS was placed on standby status in 1974. Some site facilities were preserved for future use and in 1987 were made available to government and commercial users on a full-cost reimbursable basis. This included four major space-testing facilities.

1.3 Report Organization

The report is organized into eight sections:

Section 1 – Introduction: describes the background and purpose for this project, the location and history of each facility, and the report organization;

Section 2 – State and Federal Laws: lists state and federal laws affecting protected species at the GRC facilities;

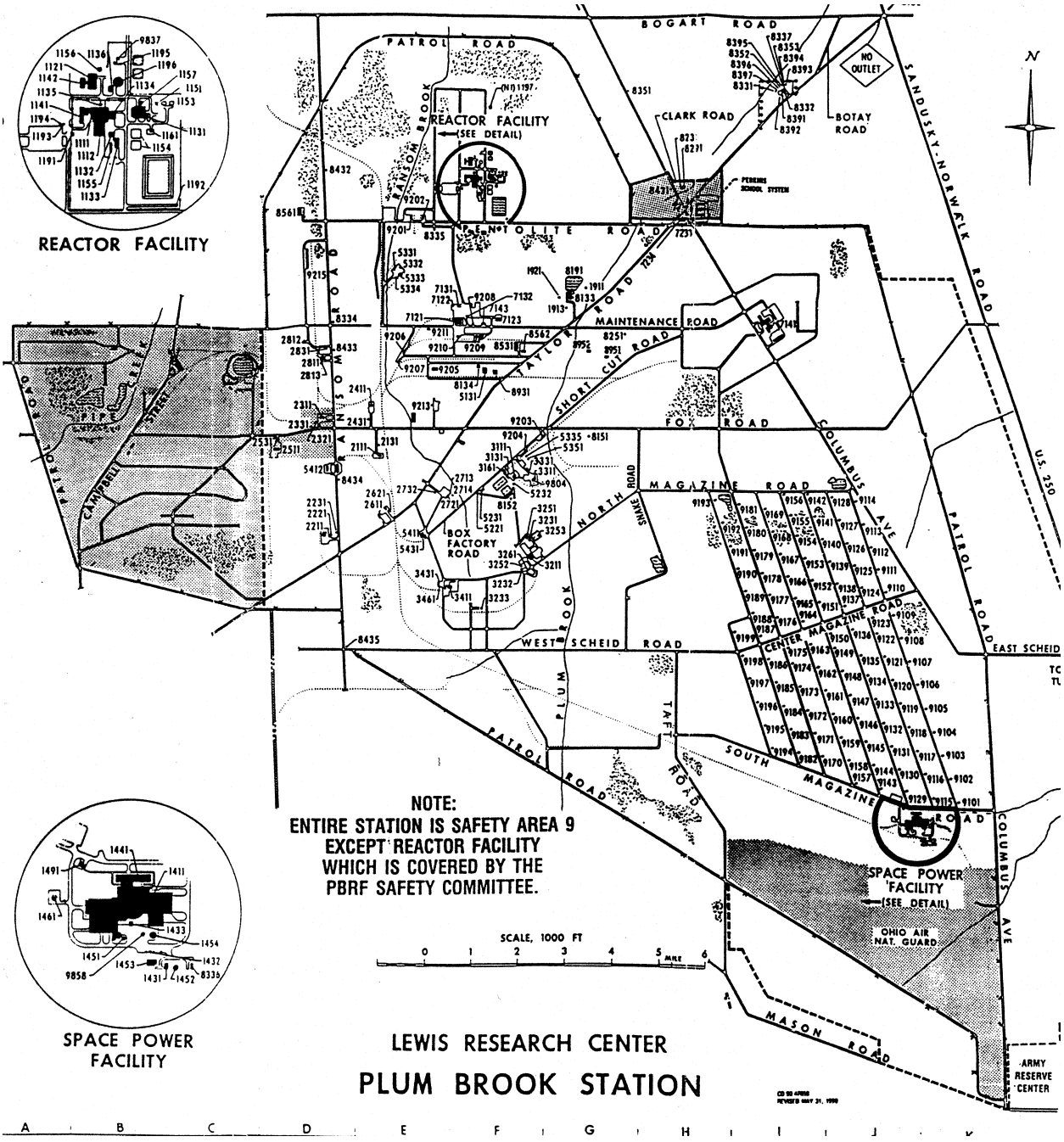

FIGURE 2. MAP OF PLUM BROOK STATION

Section 3 – Protected Species: lists the protected species that were identified during the biological surveys;

Section 4 – Areas of Special Vegetation Significance at PBS: presents the vegetation history and the locations, significance, current condition, immediate and long-term threats, and management recommendations for important plant communities identified at PBS during 2001;

Section 5 – Species-Specific Recommendations at PBS: presents specific management recommendations for protected species not covered by Section 4;

Section 6 – Areas of Special Vegetation Significance at Lewis Field: presents the vegetation history and the locations, significance, current condition, immediate and long-term threats, and management recommendations for important plant communities identified at Lewis Field during 2001;

Section 7 – Species-Specific Recommendations at Lewis Field: presents specific management recommendations for protected species not covered by Section 6;

Section 8 – Wetlands and Aquatic Resources: discusses potential wetland areas and aquatic resources at the two facilities and laws regulating them;

Section 9 – Invasive Plants: discusses invasive plants that may threaten native plant communities at the two facilities;

Section 10 – Management Techniques: discusses various methods for controlling undesirable or overgrown plants, maintaining existing native plants and plant communities, and restoring native plant communities;

Section 11 – Utilizing GIS to Support Management: describes the GIS data layers that have been developed for the project and how they may be utilized to aid the management of protected species and rare plant communities;

Section 12 - Summary: briefly summaries the report; and

Section 13 – References: lists the references cited throughout the report.

2. STATE AND FEDERAL LAWS

Compliance with state and federal laws is a primary motivation for monitoring and managing of protected species on federal property controlled by NASA GRC. Many species of animals and plants have become endangered or threatened within Ohio due to habitat destruction, harvesting and hunting pressures, and pollution. The U.S. Congress and the State of Ohio have enacted legislation to protect these species. This section describes the development laws protecting endangered species and lists those applicable to NASA GRC property.

A combined total of eleven federal and state laws dealing with various aspects of wildlife conservation and species protection are presently in effect in Ohio, including:

- Ohio Endangered Species (Plants) (ORC 1518)
- Endangered Wild Animal Lists (OAC Chapter 1501:31-23)
- Protection of Species Threatened with Statewide Extinction (ORC 1531.25, .26, .99)
- Bald and Golden Eagle Protection Act (16 USC 668)
- Migratory Bird Treaty Act (16 USC 703-711)
- Migratory Bird Conservation Act (16 USC 715)
- Land and Water Conservation Fund Act of 1965 (16 USC 460)
- National Environmental Policy Act of 1969 (16 USC 4321-4347)
- Marine Mammal Protection Act of 1972 (16 USC 1361-1407)
- Endangered Species Act of 1973 (16 USC 1531)
- Fish and Wildlife Conservation Act of 1980 (16 USC 2901)

Of these laws, the most significant is the Endangered Species Act of 1973; hereafter, abbreviated as the ESA.

The first national legislation passed specifically for endangered species was the Endangered Species Preservation Act of 1966. This Act provided only for the preservation of native endangered species. It required the United States Fish and Wildlife Service (USFWS) to prepare and maintain an official endangered species list. The official listing is codified in 50 CFR 17.11 and 17.22 and is typically updated on a regular basis.

While the USFWS was authorized by this Act to expend funds for the management of listed species and to use Land and Water Conservation Funds to acquire habitat for endangered species, it gave no authority prohibit taking, trade, or other potentially harmful acts. The 1966 legislation was amended with passage of the Endangered Species Conservation Act of 1969. The USFWS was thereby given authority to list foreign animal species and to restrict their import. This Act, however, still offered no protection for native endangered species.

The ESA of 1973 is far more comprehensive than the 1969 Act. It provides protection for all animals and plants (the 1969 Act addressed only vertebrates, mollusks, and crustaceans). It recognizes a Threatened, as well as Endangered, status category, thus establishing authority to protect threatened species before the danger of extinction becomes grave. It addresses animal populations, whereas the 1969 Act recognized no category below sub-species; and, for the first time, it provides native endangered species with real protection backed by tough penalties for violators.

Furthermore, the ESA implemented the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Convention on Nature Protection and Wildlife Preservation in the western hemisphere.

The Office of Endangered Species, USFWS, seeks such objectives as (1) the listing/delisting process for endangered species; (2) the procurement of current population data on these species; (3) the appointment of species' recovery teams; (4) the preparation of Environmental Assessments or Impact Statements; (5) determining Critical Habitat; and (6) conducting both formal and informal consultations with other federal agencies in compliance with Section 7 of the ESA. Under the provisions of Section 7, the ESA mandates federal agencies to take positive action toward protection of endangered and threatened species, wherever found on lands controlled by them.

The ESA was later amended by the Endangered Species Act Amendments of 1978. These amendments provide a mechanism for the exemption of certain federal projects from the requirements of Section 7 of the ESA. This section requires that federal actions do not jeopardize the continued existence of listed species or destroy or adversely modify their critical habitat. Applications for exemptions may be considered, however, only if made by federal agencies, by Governors in affected states, or by persons whose permit or license applications have been denied primarily because of the application of Section 7 to a federal agency's actions. These amendments authorize the President to exempt proposed actions in major disaster areas; require an exemption if the Secretary of Defense finds it necessary for reasons of national security; and authorizes the Secretary of State to block an exemption if it would violate an international obligation of the United States. Also, the 1978 amendments require federal consideration of economic impact in the determination of Critical Habitat. Exclusion of areas from Critical Habitat determinations can be authorized in certain circumstances by the Secretary of the Interior for economic reasons.

The ESA requires that all federal departments and agencies seek to conserve endangered species and threatened species and to utilize their authorities in furtherance of the purpose of the ESA. Federal agencies also are required to cooperate with state and local agencies to resolve water resource issues in concert with conservation of endangered species. Each federal agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of critical habitat. It is the policy of NASA to comply with these requirements.

Two state laws also specifically address the protection of endangered species. "Ohio Endangered Plant Law" (ORC 1518) became effective in 1978. It establishes the rules for identifying endangered species of native plants, prohibitions against unpermitted injury to and removal of endangered plants, and outlined penalties for violations. The Ohio Department of Natural Resources (ODNR), Division of Natural Areas and Preserves is responsible for managing this program.

"Preservation of Endangered Wildlife" (ORC 1531.25) establishes ODNR's Division of Wildlife as regulators of endangered wildlife in Ohio. This law, effective in 1974, also outlines under what circumstances endangered animals could be legally taken.

Neither state law requires recovery plans, critical habitat designation, or agency consultation.

3. PROTECTED SPECIES

The following is a summary of listed species located at PBS and Lewis Field during the biological surveys. No federally-listed endangered or threatened species were observed at either site during the 2001 survey. However, recently a pair of bald eagles (*Haliaeatus leucocephalis*), a federally-listed threatened species, have established a nest at PBS. Both PBS and GRC are located within the range of the Indiana bat (*Myotis sodalis*), a federally-listed endangered species. Bat surveys were conducted at both sites during 2001 and no Indiana bats were observed.

Ohio state-listed species were observed at both sites. The state list for plants is maintained by ODNR's Division of Natural Areas and Preserves. Plants listed as "endangered" or "threatened" have legal protection in the State of Ohio. Plants listed as "potentially threatened" do not have legal protection, but their status is being monitored for potentially listing for legal protection. Plants listed as "added" were recently added to Ohio rare plant list, but their designation has not yet been determined.

The state list for animals is maintained by ODNR's Division of Wildlife. Animals listed as "endangered" have legal protection in the State of Ohio. Animals listed as "threatened" or "special interest" do not have legal protection, but their status is being monitored for potentially listing for legal protection. The Division of Natural Areas and Preserves also maintains a list of rare animals, but their designations do not confer legal status. Animals on this list are included the "special interest" category below.

3.1 PLUM BROOK STATION LISTED SPECIES

3.1.1 Plants

The 1994 biological survey (ODNR 1995) reported twelve species of rare vascular plants at PBS. Two of these, *Carex alata* and *Arenaria lateriflora*, could not be relocated in 2001. The site where the *Arenaria* was located was thoroughly searched, but the species was not found. *Carex alata* is a difficult species to spot and it was rare in 1994. The species may well have been overlooked in 2001. In 2001, ten new state rare species, in addition to *Carex cephaloidea* were discovered. Many new populations of already known rare plants were also discovered in 2001. The results of this survey demonstrate that the PBS is one of the most important refuges for rare plant species and prairie remnants in northern Ohio.

3.1.1.1 State-Endangered Plants

Carex cephaloidea (thin-leaf sedge) - 2001
Hypericum gymnanthum (least St. John's wort) – 1994/2001
Juncus greenei (Greene's rush) - 2001
Prenanthes aspera (rough rattlesnake root) - 2001

3.1.1.2 State-Threatened Plants

Carex conoidea (field sedge) – 1994/2001
Hedeoma hispidum (rough pennyroyal) - 2001
Helianthus mollis (ashy sunflower) – 1994/2001
Panicum boreale (northern panic-grass) - 2001
Sagittaria rigida (deer's tongue arrowhead) - 2001
Smilax herbacea v. *lasioneura* (pale carrion-flower) - 2001

3.1.1.3 State- Potentially Threatened Plants

Arenaria lateriflora (grove sandwort) - 1994
Aristida purpurescens (purple triple-awned grass) - 2001
Baptisea lactea (prairie false indigo) – 1994/2001
Carex alata (broad-winged sedge) - 1994
Gratiola virginica (short's hedge-hyssop) – 1994/2001
Hypericum majus (tall St. John's wort) – 1994/2001
Juglans cinerea (butternut) - 2001
Rhexia virginica (Virginia meadow-beauty) – 1994/2001
Scleria triglomerata (tall nut-rush) – 1994/2001
Viola lanceolata (lance-leaved violet) – 1994/2001

3.1.1.4 State-Added Plants

Bromus nottowayanus (satin brome) - 2001
Carex brevior (tufted fescue sedge) - 2001

3.1.2 Animals

The federally-threatened bald eagle (*Haliaeatus leucocephalis*) was not observed during the 2001 study, but a pair have since established a nest at PBS. Two state-listed endangered species were observed during the 2001 survey. The state-endangered sedge wren (*Cistothorus plantensis*) was observed in both the 1994 and 2001 surveys. A single *Spartiniphaga inops*, a state-endangered moth species, was collected during 2001. Three state-threatened species and seven special interest species have been observed at PBS.

3.1.2.1 Federal-Threatened Animals

Haliaeatus leucocephalis (bald eagle) - 2002

3.1.2.2 State-Endangered Animals

Cistothorus platensis (sedge wren) – 1994/2001 (proposed to be moved to special interest effective April 2002)

Spartiniphaga inops (moth, no common name) - 2001

3.1.2.3 State-Threatened Animals

Bartramia longicauda (upland sandpiper) - 1994
Bulbulcus ibis (cattle egret) – 1994/2001(proposed to be added to endangered list effective April 2002)
Nycticorax nyctcrax (black-crowned night heron) – 1994/2001

3.1.2.4 State-Special Interest/Concern Animals

Casmerodius albus (great egret) – 1994/2001
**Dendroica discolor* (black-throated green warbler) – 1994/2001
Emydoidea blandingii (Blanding's turtle) - 1994
Elaphe vulpine gloydi (Eastern fox snake) – 1994/2001
**Oporonrnis philadelphia* (mourning warbler) – 2001
**Opheodrys vernalis* (smooth green snake) – 1994/2001
Rallus limicola (Virginia rail) - 2001

* = Division of Natural Areas and Preserves listing

3.2 LEWIS FIELD LISTED SPECIES

3.2.1 Plants

The 1995 biological survey (ODNR 1996) reported three species of rare vascular plants: *Castanea dentata* (American chestnut), *Pycanthemum muticum* (blunt mountain-mint), and *Vitis cinerea* (pigeon grape). In 1995, all three species were listed as "potentially threatened" in Ohio. This listing status is an indication of rarity rather than legal protection status. The observed increase in abundance of *P. muticum* in Ohio has resulted in the Division of Natural Areas and Preserves removing it from the list of rare species in Ohio. All three species were observed during the 2001 survey at the same locations noted in the 1995 report. No additional populations of these species were observed at Lewis Field in 2001.

3.2.1.1 State-Endangered Plants

None observed

3.2.1.2 State-Threatened Plants

None observed

3.2.1.3 State-Potentially Threatened Plants

Castanea dentata (American chestnut) – 1995/2001
Vitis cinerea (pigeon grape) – 1995/2001

3.2.1.4 State-Added Plants

None observed

3.2.2 Animals

No state-listed animals were observed during the 2001 survey. A single male black-throated green warbler was observed briefly during the survey. ODNR's Division of Natural Areas and Concern lists this species as "special concern" due to its declining numbers.

3.2.2.1 State-Endangered Animals

None observed

3.2.2.2 State-Threatened Animals

None observed

3.2.2.3 State-Special Interest/Concern Animals

**Dendroica discolor* (black-throated green warbler) – 2001

* = Division of Natural Areas and Preserves listing

4. AREAS OF SPECIAL VEGETATION SIGNIFICANCE AT PBS

The management of protected species often is accomplished through management of habitat used by these species. In this project, habitat is identified as distinct plant communities such as forests, shrublands, herbaceous fields, and wetlands. These plant communities were described and mapped in Volume II: Plant Community Survey (SAIC 2002). Many important plant communities were identified in that report. Some of these communities require management because they contain an abundance of protected species. Others do not contain rare species, but they are rare plant communities that warrant management. State and federal laws do not require the management of these areas, but federal agencies, as stewards of the land they control, may manage these areas in the interest of science and conservation.

This section addresses areas of special vegetation significance at PBS. It first presents the vegetation history of PBS to provide the context for the significant communities. The history is followed by a discussion of the locations, significance, current condition, immediate and long-term threats, and management recommendations for important plant communities identified at PBS during 2001.

4.1 Historical Context of PBS Plant Communities

The historical setting of PBS before European settlement is unique. Several rare or uncommon original plant communities occupied the site before modern settlement, including oak savannas and forests, and prairies of several types (Blakeman 1998). Proper management of PBS vegetation requires an understanding of the site's original vegetation and the ecological factors that controlled those plants and communities.

The descriptions of original vegetation below are derived from several authoritative sources. The first is from the first surveyor's field notes of the Firelands (now Erie and Huron Counties) of the Connecticut Western Reserve written in the field in the first decade of the 19th century. These field notes describe presettlement vegetation along the township and range line transects and therefore provide accurate first-hand records (Anonymous 1915). The second source of early landscape descriptions are found in several accounts in the *Firelands Pioneer,* a 19th century publication of the local Firelands Historical Society. A number of settlers recorded their recollections of early settlement days in the area in this local journal (Drake 1863 and Gurley 1863). Lastly, late 19th century atlases for each of the Erie County townships provide generalized descriptions of early settlement conditions (Anonymous 1874). Coupled with modern scientific understandings of native plant communities, an accurate description of the presettlement landscape vegetation of PBS has been constructed.

In brief, the history of PBS vegetation occurred in this sequence. Before European settlement, local plant communities were under the control of local Native Americans. Although there is no archeological evidence for significant dwellings, the area was frequently used for hunting. The combination of large open prairies, bordered by open grove-like oak savannas grading into solid forest to the north and west, provided an exceptionally wide diversity of wildlife habitats, perhaps more than any other equivalent locality anywhere in northern Ohio. These habitats supported both a diversity and large concentration of game animals (Blakeman 1998).

Most of the wild habitats or plant communities at PBS were reduced to agricultural occupation in the last half of the 19th century. The majority of the site's soils are exceptionally fertile, a result of the centuries of the soil-building prairies of much of the area. The advent of the steel plow, effective drainage techniques, construction of local transportation infrastructure (roadways, railways, inter-urban passenger train lines), and access to Lake Erie and regional railroads all combined to complete intense agricultural exploitation of the area.

By the early 20th century, most of PBS was in agriculture. The large prairie areas were probably all in either row crop fields or domestic animal pasture. A few forests and savannas persisted, but many were altogether removed and converted to agriculture. The remnant forests and savannas remained probably as grazing and firewood sources.

By the time of the conversion of PBS to an ordnance manufacturing facility in the early 1940s, there were probably few or no intact native plant communities. Any remnant high-quality prairies or

savannas that existed would have been very small, local patches. By the middle of the 20th century, the massive conversion of the site's vegetational landscape to modern agriculture was complete. Representative original plant communities were gone. Rare plants persisted only in hedgerows, field borders, roadsides, unused field corners, and other random areas.

One important distinction must be understood. Unlike other localities in northern Ohio, PBS properties were removed from agriculture at the beginning of World War II before the widespread use of chemical herbicides. Historic weed control at PBS involved only mechanical and crop rotation means. Consequently, the plant species of the original plant communities were able to persist in small, locally-isolated populations in ditches, hedgerows, field corners, and similar sites. The absence of chemical weed control allowed many rare species to persist on the site, although not in their original plant communities.

This locally unique sequence of human landuse patterns accurately accounts for the persistence the many rare plants on the site. First, these species occurred commonly in the area in large landscape-scale prairies and savannas before European settlement. Then, European settlement and landuse patterns facilitated the isolated local survival of the original plants, but not the rare communities themselves. As elsewhere, the activities of the European settlers destroyed the original plant communities. But they did not altogether extirpate the constituent plant species. These survived in waste areas and continue their local presence today.

Significant Effects of Landscape Fire

None of the historic events cited above are as significant as the frequent presence of landscape fire at PBS. The extensive presettlement prairies of the region originated in a long period of drought from 4000 to 8000 years before present, a period known as the Xerothermic. During this ancient hot and dry period, climatic factors favored the establishment of prairie communities.

But climatic patterns similar to the modern ones returned to Ohio at the end of the Xerothermic Period (at least 4000 years ago), and prairie plants and communities would have naturally reverted to native deciduous forest. This, in fact, occurred throughout most of Ohio. But in a few areas, extensive prairie landscapes persisted. These included the Darby Plains west of Columbus, the Sandusky Plains in the Marion-Upper Sandusky area, and in much of Wood County. One of the largest prairie areas was the great Firelands Prairie of Erie and Huron Counties, which included PBS (Gordon 1969).

The persistence of these prairie landscapes can be accounted for only by the frequent occurrence of landscape fire. PBS, along with the other Ohio prairie areas, has sufficient moisture and soils to support dense forests. But for centuries, frequent landscape fires prevented overgrowth of forest into the prairies. Forest trees are generally restricted by frequent fire. Prairie plants all thrive after fire. Landscape fires significantly altered normal vegetation patterns and caused the persistence of the area's many rare prairie plants (Gordon 1969).

Contrary to some theoretical explanations involving lightning, the frequent landscape fires of PBS, even in the earliest times, were deliberately set by humans. Native Americans used landscape fire in

Ohio prairies and forests for a number of important outcomes. It is known that prairie grasses growing following a fire have elevated levels of proteins. Thus, deer and other grazers were attracted to newly burned prairie areas where highly nutritious new grass promoted reproduction and successful nurturing of offspring. Burning therefore tended to attract and concentrate game animals for human use. Deer were commonly moved and concentrated by human-set "ring fires" in local prairies. Such fires were expertly used to herd deer into areas where they could be easily slain for human food and clothing (Blakeman 1998).

After settlement, European agriculturalists continued the use of fire to control vegetation in hedgerows, pastures, ditches, roadsides, and other non-crop areas, perpetuating the rare plants in these isolated refugia.

Landscape fire at PBS was absent during World War II and from the 1950s through the 1970s. Vegetation was apparently controlled by extensive mowing. At some time in the late 1960s or 1970s extensive landscape mowing ended, and overgrowth by weedy and woody shrubs began in earnest, resulting in large areas of impenetrable thickets. Later, NASA personnel began burning to control the woody plant invasion. Such burns during March and April in the 1980s and 1990s successfully restored large areas to more natural, meadow-like vegetation and restrained encroachment of woody shrubs and thickets. These modern fires emulated the historic ones and the site's rare plants, near local extirpation, responded with increased growth. These late 20th century fires saved most of the area's rare plants.

The historic prairie fires commonly burned into the adjacent wooded areas, accounting for the prevalence of various oak (*Quercus*) species, all of which are adapted to frequent fire. Fires in PBS forests created open, park-like forests with no entangling underbrush. Native Americans were known to burn forests throughout Ohio to attain this favorable condition, which enabled easy travel and increased visual security opportunities. The historic burning of PBS forest floors was as common as the burning of the open prairies.

One of North America's rarest plant communities is the oak savanna, an area with particular ground level grasses and forbs ("wildflowers") beneath scattered oaks. Unlike in authentic closed-canopy oak forests, savanna trees were spaced far enough apart to allow sunlight to reach the ground between the trees. These rare communities were a combination of prairie and forest, with many prairie plants growing in between the scattered oaks. In some areas the oaks formed a more forest-like closed canopy environment, whereas on the edges, closer to prairie, the trees became less dominant. PBS likely had a number of savannas in early times. Remnants of these persist. They are described in Sections 3.2 and 3.3.

In summary, the historical human uses of the PBS landscapes, by both Native Americans and European settlers, are unique and significant in their effects on plant communities. Most of the original plant communities are now rare.

4.2 Areas of Special Vegetation Significance

A number of sites have been identified by both field work and reference to historic data as areas of special ecological or vegetational significance. These include specific sites with identified populations of rare or state-listed plant species. They can be small and local, or somewhat extensive in area. But in all cases their distinguishing characteristic is that they support a growth of rare plants. The loss of any of these sites is likely to mean the irretrievable loss of the local rare plants, many of which are exceptionally rare or state-listed and found nowhere else in the region or state. These areas have been separated into four distinct categories, below.

Specific Rare Plant Sites

These are specific sites with identified populations of rare or state-listed plant species. They can be small and local, or somewhat extensive in area. But in all cases their distinguishing characteristic is that they support a growth of rare plants. The loss of any of these sites is likely to mean the irretrievable loss of the local rare plants, many of which are exceptionally rare or state-listed and found nowhere else in the region or state.

Intact Rare Plant Communities

These are entire, intact plant communities of ecological rarity, both at PBS and regionally. Common plant communities such as old field meadow, successional forest, and other commonplace communities are not included. Only plant communities known to be regionally rare or uncommon are listed.

Degraded Rare Plant Communities

Several rare or exceptional plant communities of ecological importance were identified in the field, but each is currently in an ecologically degraded, although not irretrievable condition. With proper management, each of these areas is likely to revert to a close approximation of its original, rare presettlement ecological conditions. These areas, even in their current degraded state, are exceptionally rare and should not be dismissed. The designation “degraded” does not in any way imply low value.

Rare Plant Community Restoration Areas

These are larger landscape areas upon which representative rare plant communities should be restored by appropriate management techniques. These areas are currently vacant with no structures or other potentially complicating features. In most cases, many of the rare or uncommon native plants already occupy the sites, but not with appropriate frequency or density. Innovative management and restoration techniques (described elsewhere) may be used in future or continuing restorations.

In most cases, many of the rare or uncommon native plants already occupy these sites, but not with appropriate frequency or density to be designated as important communities at the present time. However, these areas show promise as restoration sites for native plant communities.

The following discussion describes the location and significance of each of the rare plant or significant community sites identified during the 2001 survey. Each of these areas are portrayed on Plate 1. Referenced photos appear in Appendix A.

4.2.1 Specific Rare Plant Sites

Each of these sites has known populations of regionally rare or state-listed plant species. Most of these species are found only at these sites, not throughout PBS. Therefore, these local sites have the highest ecological value of any on the PBS. The two sites described below have the greatest density of rare plants.

4.2.1.1 East Patrol Road Rare Prairie Plant Site

Location: All lands, especially including the actual ditch area, immediately west of East Patrol Road from the intersection of Fox Road south approximately 1400 ft to a depth to the west of approximately 800 ft. In the plant community survey (SAIC 2002), this area was classified as Intermittently flooded early-successional herbaceous field.

Significance: This site contains the greatest number, both in specimens and species, of rare or state-listed plants of any location on PBS. Ohio's largest population of the very rare *Helianthus mollis*, ashy or downy sunflower, occurs here with several thousand plants (Photo 1). This showy plant was until recently thought to be extirpated from most of the state until the discovery of two local Erie County populations, this one being the largest.

Prenanthes aspera, rough rattlesnake root, an exceptionally rare (state-endangered) plant known otherwise from small isolated populations in southern Ohio, has been recently found growing on this PBS site. Several other uncommon or infrequent prairie plants are found in large numbers at the site, such as tall green milkweed (*Asclepias hirtella*), mountain mint (*Pycnanthemum tenuifolium*), arrow-leaved violet (*Viola sagittata*), common sneezeweed (*Helenium autumnale*), among others, indicating the ecological significance of the site.

Present Condition: In addition to the rare species, massive numbers of common aggressive plants are slowly overtaking the site, including one or two species of *Rubus*, wild blackberry, along with native dogwoods (*Cornus* spp.) and other woody shrubs. The site lacks large numbers of supporting native prairie grasses. Much of the area now has 2-meter high brambles (*Rubus* sp.) in massive, impenetrable thickets. No rare plants survive in the shade of these thickets. They threaten the entire locality.

Immediate Threats: Shading and competition by the overrunning woody plants, the blackberries, dogwoods, and others, directly threaten the continuance of the site's rare plant species, each of which is dependant on access to full sun. The lack of fire on the site in the last two or three years as

allowed the proliferation of threatening, undesirable species and the suppression of the native rare ones. Absence of fire in just one or two more seasons may seriously endangered the continuance of rare plants on this site as taller, shading woody plants encroach. Encroaching and shading blackberries have already captured large areas formerly occupied by the state-listed *Helianthus mollis.*

Long-term Threats: Shading, as described above, and destruction by mechanical disruption of soil structure in possible conversion of the site for other, non-natural purposes are long-term threats.

Management Recommendations: The site, as of 2001, was in dire need of restorative landscape fires during the dormant dry period in March and April each spring.

Comments: This single site should receive the highest priority for preservation and management of its rare species. Its rare species should be carefully re-seeded and reintroduced in other PBS areas, starting in the larger meadows immediately adjacent to the site, thereby reducing the long-term threats to these plants.

Other, more common prairie plants such as appropriate tallgrasses (*Andropogon gerardii*, *Sorghastrum nutans*) and forbs (many species) should be properly reintroduced to the site (and adjacent meadows) to enable long-term reversion back to original prairie conditions. The rare plants are much more likely to survive in association with a larger, ecologically functioning prairie community.

4.2.1.2 Magazine Area

Location: This area involves all of the lands in the magazine area between North and South Magazine Roads (Photo 2). The vegetation growing on the tops of the magazines, and the magazine structures themselves, is not included. But the lands surrounding the individual magazines are vegetationally significant. Plant communities in this area are highly diverse.

Significance: The magazine area has a great diversity of plant species, including many rare or state-listed ones. It also has a diversity of plant community types, including wetland sites, drier prairie-like communities, and several forest types, including wet pin oak forest [(*Quercus palustris* – (*Quercus bicolor*) seasonally flooded forest alliance].

Most significant are the frequent populations of many rare prairie species, as shown on Plate 1, in formerly excavated or disturbed sites adjacent to many of the magazine structures.

Present Condition: The vegetation of the magazine area, as stated above, varies from scattered wetlands to prairie-like meadows to forest. Forested areas, except for a few isolated small sites, appear to be mostly composed of mostly even-aged stands of pin oak. A few isolated oak forests on slight elevations appear to be older.

Brushy areas abound in edges. The most important ecological areas appear to be in the bottom of excavated areas that lack original topsoil. Very few or no non-native plants are found in these

highly-disturbed areas. The sub-soils of these excavated sites apparently harbor original mycorrhizae (specific soil fungi) or have other microbial or nutritional conditions that favor persistence of rare or uncommon native species.

Immediate Threats: Each of the significant plant species of the magazine area is threatened by shading by encroaching woody plants in the absence of landscape fire. Woody invasion is reasonably moderate in the excavated areas, but increasing significantly in edges and un-excavated uplands. Absence of recent spring landscape fires has allowed the first stages of woody plant invasion to begin.

There are several locations where rare plants and other desirable native plants are threatened by roadside mowing (see Plate 1). These populations would benefit from a cessation of roadside mowing during the growing season. The roadsides can be mowed wider in winter to prevent woody plants from encroaching.

Long-term Threats: As in other sites, mechanical disruption for construction, land "clearance," or similar activity will threaten the plant communities of this area. The greatest threat, however, will be lack of fire. As elsewhere, all significant species and plant communities are dependant on periodic landscape fire to maintain favorable growing conditions.

Management Recommendations: The magazine area plant communities can be maintained by periodic landscape fires during dormant seasons, either in late October and November (autumn) or in March or April. Vegetation in much of the area is not dense, so prescribed fires may be less frequent for woody vegetation control. Fires in the area should occur on an as needed basis, indicated by the increased appearance of aggressive woody plants. Frequent, annual dormant-season burning, however, would pose no threat to any significant plant species or community of the magazine area. Mowing along roadsides should be curtailed during the growing season.

The future re-introduction of common prairie species, such as the tallgrasses and composite flowers, among others, has the potential to restore, over time, the original prairie communities of the area. The disturbed nature of magazine landscape should not, by itself, dismiss the possibility of appropriate community restoration activities in the magazine area.

Comments: The magazine area, because of its highly disrupted landscapes, would seem to be the least likely PBS area with rare plants. But many survive and proliferate there, mostly in the disturbed areas, even in the absence of original topsoil. But the area should not be summarily dismissed. It is an important refugium of many native, original prairie species, several of which are uncommon or unknown from other PBS sites.

4.2.2 Intact Rare Plant Communities

Because of intensive agricultural and other modern human activities at PBS before its conversion to explosives manufacture, few intact plant communities of any ecological significance survive. Two existing forest areas, however, appear to be important native remnants with only minor modern disruption.

4.2.2.1 Pentolite Area Native Forests

Significant large, mature forests occur in the area north of Pentolite Road, north and west of the Reactor Facility.

Location: Much of forest north of Pentolite Road and west of the reactor facility is classified as red maple – green ash forest (*Acer rubrum – Fraxinus pennsylvanica* seasonally flooded forest alliance), a wetland category (Photo 3). A slightly less wet, but still mesic forest is present north of the reactor. This forest is classified as red oak – sugar maple forest [*Quercus rubra – Acer saccharum – (Quercus alba*) forest alliance].

Significance: The forests in this area are outside of the original pre-settlement prairie area. They represent regional forests in poorly-drained areas. Species here are, for the most part, adapted to seasonally wet soils and shaded, closed-canopy deep forest conditions. No other large mature forest sites at PBS have these conditions. Few wet forest habitats survive in the region on the Ohio Lake Plain. The forest communities of this area are representative.

Present Condition: Neither forest is "virgin," in the sense that no forestry or tree removal has occurred. Such disturbance has occurred. But a shaded closed canopy exists in most of the area, allowing the growth of representative forest floor species, including many ferns and other species adapted to wet soil conditions. Drainage by local ditches has significantly reduced seasonal hydric soil conditions of much of the area.

Immediate Threats: Continued drainage of the local soils tends to cause the invasion of species, both native and non-native not adapted to the site's original wet conditions, and reduces the persistence of original wetland species.

Long-term Threats: Wetland tree and forest floor species are likely to slowly disappear with continued drainage of the site.

Invasion of non-native forest aggressive invaders, including several Asian species of *Lonicera* (honeysuckles), as in all other Ohio forests, is a significant long-term threat.

Management Recommendations: Where possible, original drainage patterns should be re-established to restore the original soil moisture conditions to which the local vegetation was adapted. This may involve the refilling of local ditches or surface swales.

Asian honeysuckles (*Lonicera* spp.) and other foreign invaders should be monitored and removed as needed. Maintenance of a solid forest canopy will reduce or limit such invasion, but chemical control (as described by publications of the Ohio Division of Natural Areas and Preserves and other agencies) of the invaders may be required.

Infrequent dormant season prescribed fires in these forests can be somewhat restorative, as such fires are known to have occurred in original northern Ohio wetland forests. But landscape fire has the least significance in these PBS forests.

Comments: These wooded areas could be easily dismissed as being insignificant and limited in area. Few or no rare species are found here. But authentic wetland forests are rare in the region. This PBS forest area represents the remnants of forest plant communities very different from the fire-dominated prairie and oak communities in the southern portions of the Station.

4.2.2.2 West Area Native Forest

Location: This is the forest area north of South Patrol Road in the West Area (the peninsula area west of Ransom Road). It straddles a single, little-used NW-SE-trending road intersecting Taylor Road in the southwest corner of the Station. This forest is classified as the *Fagus grandifolia – Acer saccharum* – (*Liriodendron tulipifera*) forest alliance (Photo 4).

Significance: This forest area may be one of the most significant remnant forest areas in the Ohio Lake Plain. It is unique as a remarkable representation of Ohio forest conditions at the time of early settlement in the early 19th century. Early descriptions of Ohio forests universally describe their open, park-like conditions, free from underbrush or rank vegetation. This condition resulted from frequent aboriginal woodland fires. Virtually no other present-day Ohio forest exhibits these conditions, as the vigorous suppression or prohibition of forest floor fires in the 20th century has allowed vegetation patterns of brush to proliferate.

This forest area, however, accurately represents the original, native Ohio forest. Frequent burning by NASA in the last 25 years has completely restored the original, presettlement condition. Unlike in other modern-day Ohio forests, virtually no non-native plants exist anywhere in this forest (except along the non-forest road right-or-way through the area).

Except for the previous removal of mature trees, the area is "virgin," maintaining the species and structure of the original forest. From a species presence concept, it is pristine. In time, as trees age, the forest will attain absolute maturity and replicate its historical ecological structure. The only reduced element in this forest community is the absence of mature trees, resulting from previous forestry activities. But constituent species are present and growing well after frequent landscape fires.

As a plant community, this forest area is quite rare. It contains no rare or state-listed plant species but as an ecological entity it is significant as a representation of the pre-settlement Ohio forest environment, lacking only exceptionally mature trees (previously logged). All other original forest elements are present in abundance, including significant area size.

Present Condition: Virtually no non-native or ecologically inappropriate plants exist in the forest, a very rare condition in modern Ohio forests. Frequent fires have eliminated non-native species, brush and other rank vegetation, yielding a remarkable open park-like state.

Immediate Threats: Because of its high ecological integrity, there are few immediate threats. Absence of fire, however, might quickly allow invasion or growth of inappropriate species. Because this forest community is so rare, there is no contemporary experience with the speed of its degradation from fire absence.

Long-term Threats: Lack of period landscape fire will allow invasion of inappropriate species, allow the growth of "brush," and otherwise remove the natural fire-caused conditions in the forest. Logging, of course, would be a direct threat.

Management Recommendations: Maintenance of the forest's pristine pre-settlement conditions is simple: periodic dormant-season prescribed fire on the forest floor. That, alone, will maintain the community in perpetuity.

Comments: As stated above, this forest area is invaluably unique. The absence of rare species is not a consideration. Its value derives from its rare, fire-caused ecological structure that replicates the pre- or early-settlement conditions of most of Ohio's forests. No other site like this is known in the Ohio Lake Plain region, with the possible exception of a few oak forests under fire restoration procedures in the sand areas of the Oak Openings west of Toledo. Only this PBS forest accurately replicates the known conditions of the general (non-sand) forest areas of early northern Ohio.

4.2.3 Degraded Rare Plant Communities

Significant, but degraded remnants of original savanna communities are found at several PBS locations. Savannas are exceptionally rare ecological communities intermediate between oak forest and prairie. Classic prairie savannas have scattered open-growth (non-forest) oaks among prairie grasses and forbs adapted to the somewhat shaded conditions of a savanna.

Savannas are among the rarest North American plant communities, and PBS has several savannas in a degraded condition. None are pristine or currently of significant ecological quality. But their remnant structure and species composition persists, and with proper management they have the potential of significant restoration. They are classified as black oak – white oak forest (*Quercus veluntina – Quercus alba* forest alliance).

Most of the PBS sites intergrade with or approach more dense oak forest conditions. They are located in areas that were either oak forest or open savanna during the first legal land surveys of the area in the first decade of the 19th century.

4.2.3.1 South Patrol Road and Taft Road Savanna Areas

Location: This includes the entire area north of South Patrol Road, west and east of Taft Road, and south of South Magazine Road. Specifically, the original native savanna probably surrounded and included the slightly elevated area paralleling and north of Patrol Road. Larger oaks presently occupy this ridge (Photo 5).

Significance: Tallgrass prairie savannas are among the rarest North American plant communities. Virtually no others exist in the Ohio Lake Plain on mesic or hydric soils. (Sand savannas are under restoration west of Toledo in the Oak Openings, but these are very different from the oak savannas of the original Firelands Prairie of which PBS was a part.) No local savanna in good condition exists.

This PBS savanna area is one of the very few sites in all of Ohio, or even the larger Midwest tallgrass prairie region, yet open to any sort of ecological restoration. The site would not be presently regarded as an authentic savanna, but the presence of large, spreading open growth oaks, dappled ground level lighting, and the known existence of a savanna on the site in the early 19th century brings exceptional ecological significance to the site.

This is one of the rarest plant communities in the Midwest, even in its highly degraded state.

Present Condition: Most of the original savanna elements are reduced or absent, especially the presence of appropriate prairie and savanna grasses and forbs on the ground layer. Excessive brushy conditions, both by native and non-native woody aggressive have overtaken much of the site. Many large savanna oaks (mostly *Quercus velutina*), however still occupy the site and cast appropriate savanna shade.

Immediate Threats: The proliferation and encroachment of brushy, woody vegetation is rapidly overtaking large areas of the site. These plants are excluding the prairie and savanna species. The overgrowth of seedling trees and shrubs is slowly transforming the entire area into a dense forest area. In a few more years most elements of the original savanna environment will be lost.

Long-term Threats: Conversion of the site to conventional forest by normal ecological succession, in the absence of fire, will destroy the remnant savanna and complicate or prevent any future restoration of the savanna environment. Failure to use frequent prescribed fire on the site will allow further degradation.

Management Recommendations: First, remnant savanna elements such as the mature oaks should be maintained by frequent, even annual prescribed dormant-season fire. This will suppress the invading woody vegetation and promote local savanna species.

This burning, alone, will preserve the remnants of the site's savanna conditions, and slowly, over decades, encourage the reappearance of authentic savanna species. But after continued annual dormant season burns have suppressed invading plants, authentic local savanna species should be appropriately reintroduced to recreate the original savanna community. Details of such restoration are too lengthy to describe here, but this PBS area has great long-term potential for authentic savanna restoration. The site should be maintained by prescribed fire in a condition that will allow future restoration activities.

Comments: Because so few other sites in the Midwest region are open to savanna restoration on original savanna sites, this area is of high biological and historical significance. Its visually degraded state fails to convey its great ecological rarity.

Comments: This area may be even rarer than the savanna sites, as it also includes native oak forest areas. Few, if any other sites in Midwest prairie areas will allow unique long-term investigation of the little-described ecological mechanisms controlling the interactions between oak forests and adjacent oak savannas. The Taft Road Savanna-Oak Forest Area can be a continentally-significant ecological experimentation area for study of the interplay of these two rare plant communities.

4.2.3.2 Pentolite Road Savanna Area

The two oak forests of this area, especially the eastern one, possess many elements of an authentic prairie oak savanna. From Pentolite Road both areas appear to be only typical woodlots, but on-site examination reveals significant savanna elements, including both large, widespread oaks and many characteristic savanna grass and forb species (Photo 6).

Location: The entire site includes forested and adjacent open areas surrounding the forests along Pentolite Road south of the Reactor Facility.

Significance: Overall the entire site is a representative disturbed savanna site. Specifically, the eastern forest area retains many elements, both in structure and species composition, of a local savanna. It is therefore an important ecological site.

Present Condition: The ground-level plants are mostly native oak forest and savanna species, with some non-native woody invaders. A lack of fire for many decades (in pre-NASA years) has allowed smaller trees to approach maturity and convert the area to oak forest.

Immediate Threats: As in other fire-dominated areas at Plum Brook, lack of frequent periodic dormant-season ground fires will allow the proliferation of invasive woody plants that will further shade the native oak forest and savanna species. Lack of fire will also allow the growth of native tree species not adapted to fire, thereby changing the original savanna composition of the area. Reed canary grass (*Phalaris arundinacea*) and giant reed (*Phragmites australis*), two highly invasive grasses, are present in the fields and ditches surrounding both savanna areas. These species should be removed or restrained by fire and herbicide application.

Long-term Threats: Invasion by woody aggressive and non-natives will eventually obliterate any remnants of the original savanna habitat.

Disruption of existing vegetation related to U.S. Army Corps of Engineers (USACE) environmental restoration efforts associated with World War II explosives manufacture activities at this site could be significant. Much of the surrounding soil has been identified as potentially polluted and may require eventual removal. If possible, these environmental restoration clean-up activities should be conducted with as little disruption of the savanna forest areas as possible.

Management Recommendations: Frequent, annual autumn or spring ground fires, as for the other oak forest-savanna areas, are highly recommended. Re-introduction of appropriate species from other savanna areas at PBS should be eventually considered.

Native tallgrass prairie should be considered for introduction in the open meadows surrounding the forests. Existing populations of non-native cool-season grasses (reed canary grass, *Phalaris arundinacea*) and others should be eventually removed and replaced with natives.

Comments: The USACE environmental restoration activities in this area may severely jeopardize the ecological continuance or plant restoration possibilities of the area. The site is ecologically significant, but not on the level of the other two savanna areas described above.

4.2.4 Rare Plant Community Restoration Areas

A number of large PBS areas are currently in degraded meadow vegetation of little ecological significance. But these areas once supported significant natural plant communities. These are communities that can be re-introduced and restored. It would be easy to dismiss many large open areas as having no ecological value because they currently contain neither many rare plant species nor rare plant communities. They may appear only to be extensive low-value weedy or brushy landscapes.

However, these large open areas have great ecological significance. Each of the identified areas was originally tallgrass prairie, and these prairies can be returned to the sites with proper modern restoration techniques that do not involve extensive mechanical or chemical disruptions. The details of these restoration techniques, which include selected transplants, selective seeding in local nurturing sites, among others, are presented in Section 10. Native local prairie restoration on these sites can be accomplished and should be considered, especially in the provision of larger plant communities that will support many of the Station's rare and state-listed species.

4.2.4.1 Central Meadows Area

Location: This area generally includes the large open areas south of Fox Road, west of the magazine area, north of West Scheid Road, generally east of Plum Brook on the west. All adjacent meadow areas may be included (Photo 7).

Significance: These large open landscapes are unique in northern Ohio. No other similarly large, non-agricultural sites exist. In pre-settlement times these meadows were native tallgrass prairie, with perhaps a few scattered oak savanna groves. These meadows contain few non-native species, although nowhere does intact, native tallgrass prairie currently exist. The potential for authentic native prairie restoration on a large landscape scale is great here. No other existing Ohio location, especially one in public ownership, or one that was originally native prairie, has such high potential for proper prairie restoration.

Present Condition: These meadows are composed primarily of native species, most goldenrods *(Solidago* spp.) and other composites. They contain many prairie species but lack the large, supporting populations of prairie grasses. Rare plant species are found in several locations with the greatest concentration in the southeastern portion of the area (see Plate 1).

Immediate Threats: Lack of periodic landscape fire will allow the rapid invasion of both native and non-native woody and brushy plants that will overtake the entire area and shade out the existing forbs and grasses with thicket communities.

Long-term Threats: Overgrowth, as described above, by brush is a great threat. Once this occurs, brush communities provide little ground level fuel for prescribed fires intended to suppress the brush. In short, once brush overtakes the sites, they are extremely difficult, if not impossible to conveniently reclaim by fire. The open meadow character is irretrievably lost without expensive, wholesale mechanical destruction of the woody brush. Conversion to such a brushy thicket environment has occurred in various areas and brush proliferation into the great meadows is ominous. Frequent prescribed landscape fire regimes must be promptly instituted.

Management Recommendations: In the near term, annual landscape fires must be set in these meadows. In the longer period, a number of prairie restoration techniques should be experimented with toward the goal of eventually converting the entire area to a massive tallgrass prairie emulating the original historical greater prairies of the Firelands (Huron and Erie Counties). Such a restoration would provide probably the largest restored native tallgrass prairie east of Illinois and provide habitat for many, if not all, of Plum Brook's rare prairie species.

Comments: Few other sites in the Midwest lend themselves so appropriately for authentic tallgrass prairie restoration. Few present day restorations occur on land that was historically prairie. This area is so large that a variety of restoration techniques may be undertaken over many years to achieve ecological success. The area could be a major site for native plant community restoration experimentation, the results of which could have major significance across a variety of other Midwest sites.

4.2.4.2 Gateway Meadow Area

Location: This is the triangle of land south of the PBS entrance bounded by Columbus Road on the east, Maintenance Road on the south, and Taylor Road on the west (Photo 8).

Significance: The area today is a reasonably pleasant open meadow with many representative prairie species, many found, as these are on sandy substrates, including Ohio spiderwort (*Tradescantia ohiensis*) and round-headed bushclover (*Lespedeza capitata*). It has no structures or other features, thereby lending itself to appropriate prairie restoration. It is the first landscape PBS visitors encounter.

Present Condition: The area is being overrun with aggressive non-prairie plants, including crown vetch (*Coronilla varia*), brambles (*Rubus* spp.) and dogwood brush (*Cornus* spp.). Some areas are being significantly shaded and are converting to brush thicket.

Immediate Threats: Lack of fire, exactly as described in the Central Meadows Area.

Long-term Threats: Same as those in the Central Meadows Area.

Management Recommendations: As in the other meadow areas, fire must be promptly returned to this landscape to suppress the encroaching brush.

Just as described in the Central Meadows Area, this area should be returned to native tallgrass prairie, albeit with tallgrass species adapted to the slightly drier, sandy soils of the site.

Comments: Restoration of native prairie on this site would present an awesome visual introduction to PBS in most seasons. It would exhibit at the same time a neat, well-kept appearance that likewise maintains a completely wild landscape, demonstrating appropriate modern ecological landscape management techniques that use no chemicals or consume no hydrocarbons in expensive mechanical mowing programs.

5. SPECIES-SPECIFIC RECOMMENDATIONS AT PBS

The management areas and recommendations presented in Section 4 will benefit many protected species at PBS. However, some protected species are located outside of these management areas and some require management techniques or policies not covered in Section 4. Plate 1 shows the locations of all listed plants. It also shows locations where listed animals have been observed. All of these locations should be considered potential management areas, where the purpose should be to preserve and enhance populations of protected species. This section presents management recommendations not covered by Section 4 and addresses specific species, where necessary. These recommendations are organized by the biological groups that were surveyed in 2001.

5.1 Plants

In 2001, it appeared that populations of many rare plant species were recovering from excessive deer browsing that was evident in 1994. This is clearly demonstrated with the ashy sunflower (*Helianthus mollis*) population that had been heavily grazed in 1994, but was flourishing in 2001. The deer population should continue to be controlled. The rare deer's tongue arrowhead (*Sagittaria rigida*) was first located in a small pond near Columbus Avenue (see Plate 1). The population was heavily browsed, presumable by deer, and would benefit from a deer exclosure.

Invasive, non-native plants pose a long-term threat to native plant populations at PBS. Section 9 specifically addresses this threat. In any future re-vegetation activities at PBS, only native plant species should be planted.

5.2 Breeding Birds

For most protected bird species, habitat management is the primary activity needed to preserve and enhance their populations. Some species such as the sedge wren (*Cistothorus platensis*) utilize the old field and grassland areas as breeding grounds (see Plate 1 for known locations). Mowing or burning of these areas should not be conducted from April 15 through August 15. This schedule would allow many grassland species the chance at two broods. If possible, this mowing schedule

should be conducted in the Ohio Air National Guard area in the southern tip of PBS. This area contains large, unique grassland community.

Many of the rare egret, heron, and rail species that have been observed at PBS utilize wetlands and other aquatic resources. The restoration and enhancement of these resources as discussed in Section 8 would benefit these species.

The construction of a nest by pair of bald eagles (*Haliaeatus leucocephalis*) in winter 2002 is a significant event. The bald eagle is the only federally-listed species known to occupy PBS. ODNR's Division of Wildlife coordinates the monitoring of breeding pairs of bald eagles in the state. They have been consulted concerning the presence the eagles nest and have provided guidance to protect it. This guidance is contained in Appendix B.

If the mute swan (*Cygnus olor*) that was observed in a west area pond (larger of the Twin Ponds north of Fox Road) in 2001 returns, it should be removed. This non-native species is very aggressive towards nesting waterfowl. ODNR's Division of Wildlife should be consulted concerning its removal from the area.

In 2001, a nesting colony of great blue herons (*Ardea herodias*) was present at the western end of this same pond. Although not protected, habitat for this species is declining and the nesting colony should be protected.

5.3 Amphibians/Reptiles

Maintenance of diverse habitats as discussed in Section 4 and restoration of aquatic resources as discussed in Section 8.3 are the primary management recommendations for amphibians and reptiles. Blanding's turtle (*Emys blandingii*), a state-listed special interest species, was not observed in 2001. In 1994, this species was observed in the pond along Snake Road (see Plate 1). This species may still be present so this pond should not be disturbed or modified. Many rare plant species are present around this pond so the entire vicinity should be preserved.

5.4 Fish

No protected fish species were identified during the biological surveys. The restoration of aquatic resources as discussed in Section 8.3 is the only recommendation for fish species at this time.

5.5 Lepidoptera

A very large number of butterfly (53 species) and moths (450 species) were observed during the 2001 field season. One moth species, *Spartiniphaga inops*, is listed as a state-endangered. Management recommendations for butterflies and moths include maintenance of appropriate habitat and food sources. Many plants growing close to the ground, in open areas or as ground cover is forested areas, serve as larval food plants for butterfly species. Therefore, mowing or burning of these areas during the growing season should be avoided. The timing of these activities in the early spring or late fall as recommended in Sections 4 and 10 should not adversely impact Lepidoptera.

Maintenance of diverse habitats including wetlands, open fields, and forest communities will ensure the preservation of the diverse moth communities. The single *Spartiniphaga inops* moth was found in the Taft/South Patrol Road Savanna Areas. Management of this plant community as recommended in Section 4.2.3.1 as well as management of PBS areas containing prairie cordgrass (*Spartina pectinata*) will preserve habitat for this species.

5.6 Bats

Eight bat species and several maternity colonies were located at PBS during the 2001 survey. No listed species, including the federally-endangered Indiana bat (*Myotis sodalis*), were observed. PBS was found to contain healthy bat populations and efforts should be made to maintain them. The stability of bat populations is dependent on an abundant and safe source of food and rooting places. At this time, PBS is supplying a variety of safe roof sites and shown by the diversity of bats inhabiting it and the level of reproductive activity occurring. In order to ensure the continuation of the bat populations, several management policies should be implemented.

1) Maintain some of the older buildings for maternity and day roost sites,
2) Leave standing dead trees, especially those in the vicinity of the Twin Ponds in the west area. Those adjacent to and in wet areas throughout PBS and those along road and wood edges should remain intact,
3) Maintain the open areas in the Vicinity of the Twin Ponds, Snake Road pond, the Recreation Center, and intermixed with the Magazine Area,
4) Maintain small vernal pools in forested areas,
5) Maintain the forested corridors along streams and ditches,
6) Avoid use of herbicides and pesticides to the extent practicable,
7) Inspect buildings for bat usage and limit disturbance during roosting season (late spring through early fall), and
8) Consider setting aside some bunkers for potential hibernaculas for wintering bats.

6. AREAS OF SPECIAL VEGETATION SIGNIFICANCE AT LEWIS FIELD

As discussed in Section 4 for PBS, the management of protected species often is accomplished through management of habitat used by these species. In addition, some areas do not contain rare species, but they are rare or important plant communities that warrant management. At Lewis Field, the native forests along Abram Creek are significant. In addition, two rare plants species are present.

This section addresses this area of special vegetation significance at Lewis Field. It first presents the vegetation history of Lewis Field to provide the context for the significant forest communities. The history is followed by a discussion of the location, significance, current condition, immediate and long-term threats, and management recommendations for the forests along Abram Creek.

6.1 Historical Context of Lewis Field Plant Communities

The composition of the original vegetation at the Lewis Field site is unknown, but its nature can be inferred. Lewis Field lies in the Beech-Maple Forest region of the great eastern Deciduous Forest of Eastern North America (Braun 1961). Gordon (1967) classified this region as a mixture of Beech Forest, Mixed Oak Forest, Elm-Ash Swamp Forest, and Mixed Mesophytic Forest. At Lewis Field, the uplands probably were dominated a mixture of Beech-Maple and Elm-Ash forests depending on local soil types and hydrology. The Abram Creek gorge provides a microclimate for more northern species and would be classified as a southern pocket of Hemlock-White Pine-Northern Hardwood Forest (Braun 1961). Mixed Mesophytic Forest likely was present on the slopes of the gorge. The terrace of Abram Creek is too narrow to support swamp forests or riverine woodlands. The original forest cover was removed probably during the early 1800's, destroying the natural vegetation. The denuded uplands likely were cultivated and/or grazed and subsequent continuing development has prevented the land from reverting to a natural state. Unlike PBS, fire was not a major factor affecting the composition of plant communities at Lewis Field.

Most of the site is now too highly disturbed to support significant numbers of indigenous Ohio plant species. Approximately 69 hectares (170 acres) at Lewis Field are considered undeveloped. The gorge of Abram Creek and the tops of the bluffs above the valley are the only areas that retain natural qualities. These areas contain forest communities similar to their original types.

6.2 Areas of Special Vegetation Significance at GRC

Unlike PBS, relatively few sites at Lewis Field have been identified as areas of special ecological or vegetational significance. Much of Lewis Field has been developed and the facility is surrounded by developed areas. Thus, few rare plants or important communities are present. The forests of the Abram Creek gorge and the adjacent blufftops are relatively mature and have not been invaded by significant numbers of non-native species. These forests represent the most significant vegetation areas at Lewis Field.

Location: Abram Creek is a tributary to the Rocky River, which is surrounded by an extensive forest corridor (Rocky River Reservation). Three different forest communities are present. On the lower slopes near the creek, eastern hemlock – yellow forest (*Tsuga canadensis – Betula alleghaniensis* Forest Alliance) is present (Photo 9). Beech-Maple forest (*Fagus grandifolia – Acer saccharum –* (*Liriodendron tulipifera*) Forest Alliance) covers the middle and upperslopes (Photo 10). The adjacent blufftops are covered by the somewhat drier Oak-Maple forest (*Quercus rubra – Acer saccharum –* (*Quercus alba*) Forest Alliance) (Photo 11).

Significance: The three forest communities are composed of predominantly native vegetation and are similar to the pre-settlement forest communities. The forests are connected to the forest corridor in the Rock River Reservation. Two plant species listed as potentially threatened in Ohio occur at Lewis Field and both occur in these forests. A single American chestnut (*Castanea dentata*) is located on the forested blufftop above the Rocky River behind Building 500. Several pigeon grape (*Vitis cinerea*) vines are located on trees on the blufftop east of Abram Creek and south of Building

142). These species and the mature forests along Abram Creek and the Rocky River should be protected to the extent practicable.

Present Condition: The Abram Creek forests are not "virgin," in the sense that no forestry or tree removal has occurred. Such disturbance has occurred. But a shaded closed canopy exists in most of the area, allowing the growth of representative forest floor species. The forests have been undisturbed for a sufficient time that most native canopy trees are present.

Immediate Threats: There are no immediate threats to these forest communities.

Long-term Threats: Invasion of non-native forest aggressive invaders, including several Asian species of *Lonicera* (honeysuckles), as in all other Ohio forests, is a significant long-term threat. Potential development at Lewis Field also is a long-term threat, but the steep slopes of the gorge likely will preclude any development in most of the forest areas.

Management Recommendations: Asian honeysuckles (*Lonicera* spp.) and other foreign invaders should be monitored and removed as needed. Maintenance of a solid forest canopy will reduce or limit such invasion, but chemical control (as described by publications of the Ohio Division of Natural Areas and Preserves and other agencies) of the invaders may be required.

Following remedial action at the former firing range adjacent to Abram Creek, the area should be restored by planting native vegetation consistent with species found in the adjacent forest communities.

Comments: These wooded areas have aesthetic as well as ecological value. Large forested tracts are rare in urban environments and all should be preserved to the extent practicable. They provide site employees an enjoyable landscape whose presence and appearance can sustain and improve morale.

7. SPECIES-SPECIFIC RECOMMENDATIONS AT LEWIS FIELD

Only two listed species, pigeon grape (*Vitis cinera*) and American chestnut (*Castanea dentata*), are located at Lewis Field. In general, the primary management recommendation for these species should be to maintain the plant communities within Abram Creek gorge and the adjacent blufftops as discussed in Section 6. Non-native species should not be planted anywhere at Lewis Field, especially near or within natural areas. The vines of the pigeon grape (*V. cinerea*) should remain undisturbed on the east side of the Abram Creek gorge. No specific management is recommended for the American chestnut (*C. dentata*). The single individual at GRC has chestnut blight (*Endothia parasitica*) lesions and likely will die within a few years.

8. WETLANDS AND OTHER AQUATIC RESOURCES

Both PBS and Lewis Field contain aquatic resources, including wetlands. At Lewis Field, Abram Creek is the primary aquatic resource. Several man-made ditches and ponds also are present. At

PBS, several small named creeks, including Plum Brook, Pipe Creek, Ransom Brook and Taylor Ditch, flow through the site. There are number of small ponds, some man-made, and many wetland areas. These aquatic resources provide habitat, foraging ground, and breeding areas for many species, including rare species. Federal and state laws specifically regulate aquatic resources. These regulations are discussed briefly in this section. Wetlands are important habitats for many rare species, so the identification of these areas also is discussed. Restoration of aquatic resources is discussed briefly at the end of the section.

8.1 Laws and Regulations

Waters of the United States, including wetlands, have specific legal protections under the Clean Water Act (33 USC Part 1344) and Rivers and Harbors Act (33 USC Part 403). The U.S. Army Corps of Engineers (USACE) has the principal regulatory program (33 CFR Parts 320 – 336) enforcing these acts. The U.S. Environmental Protection Agency, U.S. National Marine Fisheries Service, and U.S. Natural Resources Conservation Service also have regulatory authority for enforcement of specific aspects of these laws.

Several sections of the Clean Water Act are pertinent to aquatic resources at the NASA facilities. Section 101 specifies the objectives of the Clean Water Act, which are implemented largely through Title III (Standards and Enforcement), Section 301 (Prohibitions). The discharge of dredged or fill materials into waters of the United States is subject to permitting specified under Title IV (Permits and Licenses) and specifically under Section 404 (Discharges of Dredge or Fill Material). Section 401 (Certification) specifies additional requirements for permit review particularly at the state level.

Both PBS and Lewis Field are located within the jurisdiction of the USACE-Buffalo District. The regulatory branch of this district should be contacted concerning any issues related to compliance with Section 404 of the Clean Water Act. The Ohio Environmental Protection Agency (Ohio EPA), Division of Surface Water should be consulted concerning issues related to compliance with Section 401 of the Clean Water Act.

In January 2001, the U.S. Supreme Court determined that isolated wetlands (i.e., those not connected to navigable waters) should not be federally regulated under the Clean Water Act. In response, the State of Ohio passed House Bill 231 in July 2001 to set up a permanent regulatory structure for isolated wetlands. As such, isolated wetlands continue to be regulated in Ohio and a dredge and fill permit is required prior to initiating any dredge or fill activities in these wetlands.

8.2 Wetland Identification

Wetland delineations were not performed during the plant community survey (SAIC 2002), but the plant community classification system can be used to identify potential wetland areas. The Coward (1979) System is used by the USFWS to designate potential wetland areas. The following lists of PBS and Lewis Field plant community formations are potential wetland areas. They are organized according to their corresponding Cowardin (1979) wetlands classifications for system (e.g., palustrine) and class (e.g., emergent). All wetlands at PBS and Lewis Field are believed to either palustrine or riverine systems. Note that formations do not distinguish position in the landscape as

the Cowardin System does. Therefore, PBS and GRC formations listed below may be either riverine or palustrine systems depending on proximity to river or stream systems. However, due to the lack of a large stream or river at PBS, most formations would be considered palustrine systems. No formations at PBS or Lewis Field are believed to be estuarine, marine, or lacustrine systems according to the Cowardin classification.

Palustrine or Riverine Aquatic Bed (PAB or RAB)

V.C.2.N.a. Permanently flooded temperate or subpolar hydromorphic rooted vegetation

Palustrine or Riverine Emergent (PEM or REM)

V.A.5.N.k. Seasonally flooded temperate or subpolar grassland
V.A.5.N.l. Semipermanently flooded temperate or subpolar grassland
V.B.2.N.c. Intermittently flooded temperate perennial forb vegetation

Palustrine or Riverine Scrub-Shrub (PSS or RSS)

III.B.2.N.c. Intermittently flooded cold-deciduous shrubland
III.B.2.N.f. Semipermanently flooded cold-deciduous shrubland
III.B.2.N.g. Saturated cold-deciduous shrubland

Palustrine or Riverine Forested (PFO or RFO)

I.B.2.N.d. Temporarily flooded cold-deciduous forest
I.B.2.N.e. Seasonally flooded cold-deciduous forest

Neither the formation classification nor the Coward System is a reliable indicator of jurisdictional status under Sections 401 and 404 of the Clean Water Act. However, they both narrow down the list of possible areas likely to contain jurisdictional wetlands. Accurate interpretations of jurisdictional status require a site-specific field delineation in accordance with the 1987 *Corps of Engineers Wetlands Delineation Manual* (USACE 1987). If any dredge or fill activities are planned for areas that may contain wetlands, then formal delineations should be performed to determine if jurisdictional wetlands are present.

8.3 Restoration of Aquatic Resources

Aquatic resources at PBS include small streams, ponds, and wetlands. The small, intermittent nature of the streams coupled with the past channel modifications limit the options available for improving aquatic communities. The establishment of wooded riparian corridors, where they are absent, would help maintain more favorable water temperatures and would eventually improve instream habitat (pools, riffles, and runs, root wads and woody debris). These activities would enhance the recovery of fish communities, but source populations from outside PBS may need to be introduced to assist in the recovery.

A few redwater ponds are located at PBS. These ponds formerly were used in the munitions-production processes that occurred at PBS during the 1940s. The USACE has responsibility for addressing any issues related to contaminants in the redwater ponds. Investigations of the ponds are ongoing and a decision has not yet been made concerning the need for remedial action. Fish species present in PBS ponds are all common species and do not warrant special consideration unless improvement/enhancement of these ponds for recreational fishing becomes a management goal.

At Lewis Field, Abram Creek is contaminated with de-icing compounds in runoff from the adjacent Cleveland Hopkins International Airport. This contamination has adversely affected the stream biota in Abram Creek for many years. The Airport is conducting investigation and remediation activities to eliminate future contaminant releases. If successful, these activities should result in natural restoration of stream biota. NASA should not need to perform any additional activities. The creek should be monitored following the completion of remedial activities to ensure that the creek is recovering.

Wetlands restoration is not required at either facility; however, it may be considered as part of the restoration of rare plant communities discussed in Sections 4 and 6. Much of PBS likely contained wetlands communities prior to agricultural development. The extensive drainage ditch system now maintains many areas in a much drier state. Removal of some of these drainage systems would facilitate the restoration of native plant communities and a proliferation of rare species that reside in or otherwise utilize wetlands.

Successful wetlands restoration requires the restoration or creation of the three primary indicators of wetlands: wetland hydrology, hydric soils, and wetland vegetation. Wetland hydrology requires the continuous inundation or saturation of surface soils for a minimum of two weeks during the growing season. Hydric soils exhibit specific properties such as gleying as a result of anoxic conditions during saturation or inundation. Creation of hydric soils requires many years so it is best to perform wetland restorations in areas that already contain hydric soil. The USFWS National Wetlands Inventory maintains lists of wetland vegetation for each ecoregion. The lists classify plant specifies according to level of adaptation to anoxic soil conditions. A wetland must contain greater than 50% obligate wetland plants (OBL), facultative wetland plants (FACW), and/or facultative plants (FAC). If wetland restoration is considered, NASA should consult a wetland professional to assist with site selection, design, construction, and monitoring. In addition, because the restoration may involve alterations to hydrology, NASA may need to apply for a general permit from USACE covering the proposed restoration activities.

9. INVASIVE PLANTS

There are more than 700 non-native plants species in Ohio; however, less than 100 are invasive in natural areas. ODNR's Division of Natural Areas and Preserves has classified invasive species into three categories based on degree of invasiveness: targeted species, well-established non-natives, and watch list species.

- **Targeted Species:** these species are some of the most invasive in natural areas and are well established in the state,
- **Well-established Non-Natives:** these species are also invasive statewide, yet may be less of a problem in natural areas, and
- **Watch List:** these species are only established in specific regions of Ohio, yet are potentially very invasive.

Invasive species included in each of these lists are presented in Appendix C. Appendix C also indicates which of these species are known to be present at PBS and/or Lewis Field. ODNR's Division of Natural Areas and Preserves has prepared fact sheets on 18 of the most invasive, non-native species. The fact sheets present detailed descriptions and management options for these species. Copies of the fact sheets are included in Appendix C.

The natural areas at Lewis Field do not contain an abundance of any of the invasive, non-native species. However, these areas should be checked annually for the presence or increase in abundance of invasive, non-native plants. Asian honeysuckles (*Lonicera* spp.) are a likely future invader of the forest communities. If detected, management options presented in the fact sheets should be considered and implemented where necessary.

At PBS, 25 invasive species are known to be present. Some species are widely distributed and mixed with native species. Others are present as dense populations and in some cases as monocultures. These dense populations are the easiest to identify and to manage. Pure stands of giant reed grass (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*) are present in several locations at PBS, including the ditches and open fields south of Pentolite Road (near the reactor facility) and in ditches near the Space Power Facility. These species pose a particular risk to wetland areas. Management options contained in the fact sheets should be utilized to control these species.

Asian honeysuckles (*Lonicera* spp.) also are present at PBS in the forest communities. While not overly abundant at this time, their populations are likely to increase in the future without proper management. Management options presented in the fact sheets should be considered to control these species.

Populations of other invasive species should be addressed wherever they are identified. None of the species listed in Appendix C should ever be deliberately planted at either facility.

10. MANAGEMENT TECHNIQUES

This section presents general methods for managing natural resources at PBS and Lewis Field. The methods are focused on the management of plant communities because as stated previously, the management of individual rare species is often best accomplished through management of their habitat. Plant communities are the primary component of habitat at most areas at PBS and Lewis Field. Active management is more important at PBS than at Lewis Field; therefore, the techniques specifically discuss PBS. However, many of these techniques, except prescribed burns, also may be

considered for use at Lewis Field. Additional information on prairie restoration can be found in published sources such as *The Tallgrass Restoration Handbook for Prairie, Savannas, and Woodlands* (Packard and Mutel 1997).

10.1 Control of Undesirable and Overgrown Plants

This section outlines techniques that should be used to control the undesirable growth and proliferation of unwanted plant species, especially those that endanger PBS's rare plant species and rare plant communities.

10.1.1 Mowing

Conventional mowing has been a general practice at PBS for many years. The visual and physical results of modern mowing, whether along roadways or around buildings, are so well known as to require no special comment here. Conventional grounds and roadside mowing practices are acceptable and seldom affect the subjects of this document.

However, the incursion into some "wild" areas or margins along PBS roadways by excessive mowing has been noted during the 2001 growing year. Mowers have extended mown roadside margins into formerly un-mowed areas, retarding the growth of desirable native plants and hastening conversion to conventional roadside "weeds" and grasses of no ecological importance. Future mowings should be restricted to conventional narrow rights-of-way, saving mowing costs and reducing the loss of wild landscapes that may support important wild plant species.

Mowing of "wild" or rough meadow areas around buildings and in other areas not identified as significant areas for prairie or savanna preservation or restoration, which includes large portions of PBS, is not at all objectionable. Indiscriminate or unintentional mowing of ecologically important areas, however, should be prevented or restricted to specific actions based upon desired vegetation outcomes. Mowing to create large rough turf areas will be expensive to establish, difficult and expensive to maintain, and will likely degrade rapidly into hard-to-control weed and brush landscapes upon cessation of mowing.

Mowing in presently un-mown areas should be done judiciously, for only expressed, known, desirable outcomes. Mowing is very appropriate in all areas where fire is inappropriate.

10.1.2 Burning

Prescribed burning is the only economically and ecologically effective technique to control unwanted vegetation on most PBS landscapes. PBS landscapes have a long history of fire extending back several thousand years with continual annual landscape fires set by Native Americans. This PBS fire history is described in Section 4. Virtually all PBS plants and plant communities are adapted to frequent landscape fire. Therefore, landscape burning at PBS has few, if any, untoward effects. It is "natural" and beneficial. Such burning poses virtually no threats to rare plants and plant communities. More importantly, fires promote these rare biological elements. Consequently, fire should be used extensively to control PBS vegetation.

10.1.2.1 Fire in Meadow Areas

Meadow areas, open landscapes with few or no trees, should be initially burned on an annual basis until the presence of small woody and brushy plants is infrequent. Meadow (prairie) fires accomplish two goals:

(1) Removal of accumulated dead vegetation (duff) to facilitate new growth, and
(2) Suppression or elimination of undesirable woody or brushy vegetation.

Both accumulated duff and brushy vegetation shade and retard the growth of the prairie meadow plants, which further promote invasion and dominance of woody plants. Without fire, meadow areas convert to brushy landscapes, which then slowly progress to dense shrubby thicket or low forest. This process of succession can take decades, resulting in highly degraded and biologically corrupt landscapes composed of large numbers of non-native species.

Consequently, prescribed fire is highly recommended in appropriate prairie and meadow areas away from existing mechanical and infrastructural facilities for which fire would be a known hazard.

Prescribed burning should follow Ohio EPA regulations. Ohio EPA regulations allow prescribed fire for recognized biological purposes such as those being addressed in this document.

Additionally, Ohio Revised Code Section 1503.18 may apply. New interpretations of this law by the Ohio Division of Forestry requires the presence of a Certified Ohio Prescribed Fire Manager, a written burn plan, and an expressed written waiver from the Chief of the Ohio Division of Forestry before prescribed fires may be ignited outside of Ohio city limits between 6:00 am and 6:00 pm during the months March, April, May, and October and November. The details of this Division of Forestry program are still under development.

Because of the large number of intersecting roads at PBS, the chance of escape of landscape fires is minor. Landscape fires in most PBS areas are contained by existing roadway fuel breaks. In some areas, fuel breaks may have to be created by the close mowing of fuel break lanes during a previous growing season. Details of effective fire management and control in meadows and prairies are well described in other literature and utilized by many Ohio agencies and contractors who annually burn prairies. These include most county park systems, the Ohio Division of Wildlife, The Nature Conservancy, members of the Ohio Prairie Association, Pheasants Forever, and county soil and water conservation districts, among others.

In short, the burning of prairies and meadows is no longer infrequent and the techniques used are no longer mysterious or unpredictable. The techniques used by other agencies and personnel can be effectively used at PBS. Most Certified Ohio Prescribed Fire Managers would find that PBS lends itself well to these fires.

10.1.2.2 Meadow Fire Frequency

For a number of years at PBS, landscape fires were set each spring, but in biennial alternation between the north and south halves of PBS. This minimized costs while still controlling vegetation.

This sequence of alternate-year burns, however, eventually failed to accomplish effective brushy vegetation control, as can be noted by the expanded proliferation of brush currently at many PBS sites. Initially, biennial burns seemed to suppress brush. But continued biennial burns failed to properly control woody vegetation for two reasons. First, many brush species, including the brushy dogwoods (*Cornus* spp.) are not killed by a single burn. Above-ground stems are killed, root systems continue to grow and sprout new stems, especially during a second non-burn year. Alternate year burns, therefore, actually slowly increase the vitality of the brush. The plants are slightly invigorated by these fires. They grow back the following year with increased vitality, usually with multiple new stems. The proliferation of strong, multiple-stemmed dogwoods is evident throughout PBS.

Secondly, the alternate year burn cycle was occasionally disrupted by wet springs that restricted or prevented landscape fires, resulting in ever more vigorous brush growth. Today (the 2001 growing season), much of PBS is rapidly converting to brush. No landscape fires have occurred in the last two or three years on most sites, and PBS's fire-adapted species are now endangered by the expanding brush.

Annual spring (or in some cases, fall) burns obviate these brush encroachment problems. First-year fires appear to suppress brushy species, as above-ground stems appear to die back. Not until the end of the second year is the expanded re-growth of brush noticed. But a fire in the second year again destroys new stem shoots of the brush. This markedly reduces the vigor of the plant, and its re-growth in the third year is more difficult. A consecutive fire in a third year often causes the actual death of brushy species.

Therefore, initial fire sequences must be, wherever and whenever possible, strictly annual, with no interruptions. Annual fires were common in presettlement times. All of the rare native species are adapted to and thrive in such environments. Meadows and prairies should be burned annually, at least three years consecutively to effectively suppress brush. Some areas will require a longer annual burn sequence. The defining factor will be the presence or absence of even small woody stems among the meadow plants at the end of each growing season. If even a few such stems are noted in August or September, a fire the following spring is indicated. If none can be found, fire may be disregarded the following spring.

The administrative tendency, however, after these favorable conditions have been met, will be to forgo fire altogether, as the lack of brush appears complete. But here, after no annual fires, accumulated duff will increasingly shade the meadow or prairie. This will result in the decline of most rare plants and the encroachment and eventual domination by undesirable and non-native plants. Instead of brush causing a decline, undesirable non-woody species will intrude. Either way, whether shading by brush or shading by accumulated dead meadow plant material, the integrity of the native meadows is endangered.

In summary, meadow and prairie fires, to be effective, must be frequent and continued. In most areas at least three years of consecutive burns are indicated as a first step, with some requiring extended annual burns until brush and non-native plants are effectively suppressed or eliminated. After the initial brush-suppressing fire sequences have occurred, repeated annual fires should continue with periodic one- or two-year non-burn intervals.

These annual variances should be dispersed around the station to create a mosaic-like pattern of burned and unburned areas. This will allow the survival of prairie invertebrates (for example spiders, moths, and others) in adjacent unburned areas.

Details of long-term meadow burning regimes should be addressed in the future by parties with experience and expertise. But the items described here should apply.

10.1.2.3 Fire in Forest and Savanna Areas

Many of PBS's wooded areas are dominated by oaks, trees that are adapted to frequent ground fires. In recent years two circumstances have occurred that have degraded the ecological integrity of both the native oak forests, and the several former savanna sites. (A savanna is an oak forest with specific prairie-like grasses and forbs on the ground level.) First is the invasion of several species of non-native woody shrubs, including several species of Asian honeysuckles (*Lonicera* spp.), and autumn and Russian olives (*Eleagnus* spp.). These species rapidly overtake sites, both in open meadow areas and in forest edges. Their aggressive growth overwhelms native species.

The second circumstance is the recent cessation of landscape fire at PBS. This has allowed the overgrowth of both non-native aggressive species and native woody plants to the extent that naturally open woodland areas are now unnaturally brushy and congested in most areas.

Appropriate woodland and savanna fires will tend to (but may not completely) control the woodland brush. In areas with minor incursions of brushy species, fires will markedly control expansion. But the fires must be frequent and continuing. Single fires will only slightly retard brushy growth. Several years of successive fires will be required to restore natural oak forest and savanna conditions.

10.1.3 Physical or Mechanical Removal of Vegetation.

Physical removal, the hand or mechanical cutting for the control of unwanted weeds, brush, and trees, may be appropriate in specific, isolated areas. The appearance of new aggressive weeds in new areas are often best controlled by simply plucking and removing the young plants.

But because of the size of PBS, this may not be a frequently-used plant control method.

10.1.4 Herbicide Application

Proper use of herbicides is an important, even crucial, element in effective modern vegetation control. Broadcast applications of herbicides are not envisioned for plant control at PBS. But hand

or spot spraying of individual plants or small plots should be provided for. Spot applications of glyphosate, the generic component of Roundup ®, should be used to control small local populations of undesirable weeds and brush. Product label instructions should be followed.

10.2 Support and Maintenance of Plants and Plant Communities

This section outlines techniques that should be used to attain long-term maintenance of high-quality plant communities and their constituent rare species after near-term dangers have been suppressed or controlled as described in Section 10.1 above.

10.2.1 Mowing

Conventional mowing, as described above, will maintain roadside rights-of-way and similar areas. Mowing can also maintain conventional (but not prairie) meadows in areas where fire is a hazard. Mowing is a conventional practice that needs no further explanation here, with reference to the comments on mowing in Section 10.1.1 above.

10.2.2 Burning

The use of fire to support and maintain meadows and forests at PBS is essentially the same as for the control of undesirable vegetation described in Section 10.1.2 above. Prescribed landscape fire, whether for initial control of expanding brush, or for the continued long-term maintenance of rare plant communities, is essential. The absence of fire, even after brushy species have been controlled, will result in the resumption of woody encroachment. Prescribed fire must be a continued element of proper ecological management of most PBS plant communities, especially the rare prairies, savannas, and oak forests.

10.2.2.1 Fire Sequence and Frequency

Historically, Native Americans set fires on PBS landscapes annually over centuries. Native PBS plants are adapted to, even require, such continued fire. Consequently, annual prescribed landscape fires should be a standard practice.

But once woody invasive plants (brush) have been markedly suppressed or removed by annual fires, annual burns on all sites is not necessary. Fires should continue to occur frequently, but continued annual fires on all sites is not advised. Instead, annual fires at PBS should eventually create a large mosaic, patchy pattern of occurrence. Many or most areas will be burned, with many adjacent sites unburned. Instead of setting fire to the entire PBS each year, annual burning can involve between 50 and 75 percent of normally burned areas. In effect, approximately one fourth to one half of normally burned areas will not be burned in any one year after natural conditions are restored.

This reduces costs associated with setting and monitoring landscape fires, and allows for scattered “refugia” for the maintenance of various arthropods such as uncommon moths, butterflies, and other less-recognized invertebrates that are markedly reduced by continuing annual fires. Allowing some

areas to remain unburned also provides nesting habitat for some bird species that prefer dense, unburned prairie vegetation.

In summary, initial fires must be frequent and annual, but eventually should be dispersed in a mosaic pattern of large patches throughout.

10.2.2.2 Fire Location and Size

As described above, fires should be widely dispersed, not confined as per recent practice on a strict, alternating north-half, south-half annual sequence. Landscape fires at PBS are best confined by existing roads which act as fuel breaks. Consequently, continued maintenance fires can occur within areas bounded by existing roads.

If indicated by field conditions, smaller, more localized fires are certainly appropriate. Such fires might require specific mowing of confining fuel break lanes, or other accepted techniques.

No specific fire location or size formulas can be stated here. Field conditions, varying from year to year and from site to site, must dictate appropriate management responses. Consequently, individuals or firms with both appropriate landscape fire experience and ecological management of rare plant communities should be engaged periodically to professionally advise on these matters.

10.2.2.3 Fire Seasons

Meadow and prairie areas, in most cases, should be burned in March or April, when vegetation is dry and flammable. This spring burning in some cases, however, can result in a proliferation of grasses and suppressing of forbs. Presently, spring burns are not detrimental on any PBS site, as grasses seldom dominate. But in the future, this may need to be considered.

Currently, however, spring burns are recommended for prairie and meadow areas. Trial variances to gain experience and note local responses are appropriate. There needs to be no rigid prescription. The real goal is to attain desired responses by the burned vegetation, and this may require trial and experimentation. The general recommendation for spring meadow burns stands, but the PBS landscape manager should not feel rigidly confined to this recommendation. Fall burns may be appropriate for selected sites.

Prescribed burning of wooded areas, the oak forests and savannas, should occur when such fires are most effective. Experience from other areas indicates that both early spring and late autumn fires can be useful, but success depends upon specific local conditions. The decision to burn PBS forests and savannas must derive from small local trial burns and observed field annual conditions.

10.3 Growth and Restoration of Plants and Plant Communities

This section outlines methods by which rare plant species and plant communities can be grown and restored in larger populations, significantly removing them from environmental threats of local extirpation.

10.3.1 Transplantation

Several significant plant species at PBS are both regionally and locally rare and presently grow at single, isolated sites. For example, *Helianthus mollis*, ashy sunflower and *Prenanthes aspera*, rough rattlesnake root, are found at only one PBS location. Any disruption of this site may cause the local extinction of these species.

Consequently, it is appropriate to transplant a small population of these and similar species to other PBS sites where they have the potential of expanding their populations. All of the rare species at PBS were certainly more locally widespread in presettlement times and can grow on other local sites. Therefore, an effective program of on-site re-seeding or transplantation should be considered.

The details of such transplantation should be determined by personnel experienced in such matters. The Nature Conservancy, members of the Ohio Prairie Association, other similar professional organizations will be able to provide references to appropriate parties with prairie and rare plant propagation experience.

In short, without effective relocation and re-establishment in new locations at PBS, most of the rare plants will continue to be in continued danger of extirpation.

10.3.2 Field Seeding and Planting

Most plants are naturally wild-seeded and establish themselves across broad ranges. Consequently, those plants are common. But rare and uncommon plants, such as those at PBS, do not easily re-seed themselves. They remain confined to small or localized areas and can occupy larger areas only with human assistance in modern times. Several innovative techniques may be undertaken to expand the local populations of rare and uncommon plants and plant communities.

10.3.2.1 Small Inoculation Plots

Many large meadows at PBS are appropriate areas for prairie restoration. These areas include, among others, the Central Meadows west of the magazine area and the large triangular meadow just south of the main NASA gate. Each of these supports native prairie vegetation, but not in an intact prairie community.

Prairie seeds and plants should be reintroduced to such areas. But seeds sufficient to plant such large areas are not available. Instead, small plot inoculation is proposed. In this procedure, a method devised by local Erie County prairie biologist John A. Blakeman, a small area in a meadow, typically 0.5 meters by 10 meters is sterilized by herbicide spray or mechanical removal of vegetation. Local seeds are harvested and planted in the prepared strip in the meadow. The introduced prairie seeds grow and produce a small, idealized prairie and are allowed to go to seed each season.

The seeds then disseminate by wind into the adjacent existing meadow where, under the advised regimen of annual fire, they germinate and slowly re-establish themselves and further spread in ensuing years.

This method is slow, but effective. Complete restoration of the local prairie may take several decades, depending upon the frequency of prescribed fire and the number and distance between inoculation plots. Such inoculation may be the most efficient method of restoring PBS prairies. The plot areas may have to be fenced to exclude grazing by deer, and the areas may have to be hand weeded or otherwise tended during the first years of growth. But once established, the inoculation plots will continue to produce an annual rain of desirable prairie seeds.

10.3.2.2 Large Area Seeding

Large prairie meadow areas may be established by mechanical seeding involving a tractor and a specific native grass seed drill. Such equipment has been used extensively in prairie restoration by several state and county conservation agencies in Ohio. It is very effective, but likewise expensive, and often results in prairie areas with restricted biodiversity (limited number of native species).

Large area seeding first requires proper site preparation, which includes chemical or physical removal of existing vegetation, much in the manner of preparation of a field for conventional agriculture. Appropriate prairie seeds, if available, are planted with a prairie seed drill implement. The area must be mowed several times at a four to six inch height during the first season of growth, to suppress annual weeds. Some mowing may be required in the second or third year after planting. Finally, maintenance requires only annual burning, as described above.

There is much experience with this method in Ohio. But it is not highly recommended for PBS, for these reasons. First, to be successful in this technique, the seeds must be placed in bare soil free from existing plants that out-compete the prairie seedlings. This will require the destruction or removal of existing PBS vegetation, which on most sites already contains existing rare meadow plants. Destruction of the existing vegetation, to prepare the site for effective seeding, will destroy many desirable plants, many of which there will be no source for new seeds. The disruptive features of this technique are probably too great to consider at PBS.

Secondly, there is no source for appropriate seeds in the large quantities needed to seed multi-acre plots. Standard specifications for such plantings require five to ten pounds of native prairie grass and forb seeds per acre. Such quantities of local plants are not available.

Seeds from Wisconsin or other Midwestern sources are available, but because these plants originated in prairie areas with different climates, soils, and season lengths, it is not recommended that they be introduced to PBS. *For ecological and genetic integrity, no wild plant species from any other area, even in Ohio, should be planted at PBS.* That provision alone, will eliminate any possibility of large area seeding, at least until local PBS seeds could be harvested and replanted.

The specifics on these techniques are well described in the modern prairie restoration literature and by prairie experts, and they should be consulted should NASA consider large scale seeding.

10.3.2.3 New Site Creation

The existing research nuclear reactor at PBS is being decommissioned and will be dismantled, leaving a bare site open to native plant re-planting. This would be an ideal site for the re-establishment of a representative local prairie or savanna community. The details of such an endeavor do not fall under the purview of this document, but such a native plant community planting is highly recommended. This planting is likely to involve features of the items described above. The most important consideration is the ecological significance of the new plants to be restored on the reactor site. They should be local species, from local, on-site, sources, not commercial offerings from out-of-state suppliers.

Similar considerations should be applied to any sites disturbed by Formerly Used Defense Sites work of the USACE related to WWII explosives manufacture at PBS.

10.3.3 Species Propagation

PBS is a last refuge for several rare Ohio plants and plant communities. Therefore, these plants should be propagated and made available for expanded plantings at PBS itself, but also in other local natural prairie restorations. Much of both Erie and Huron Counties, Ohio were prairie, savanna, and oak forest in presettlement times, with expansive areas of each community. These rare plant communities and their plants are now virtually extirpated from the local region, with PBS hosting their last remnants.

But there is an emerging ecological movement to restore and utilize native plants for horticultural and landscape uses. The biological resources of PBS should be made available to the prairie restoration community for appropriate uses on other community sites, such as local natural parks sites (Erie MetroParks), school site natural history restorations, and similar sites.

Toward those ends, qualified individuals or public agencies should be encouraged and allowed to collect designated seeds from designated species from designated PBS sites for designated public educational and environmental enhancement purposes. It may be appropriate to form a local PBS Native Plant Advisory Council to assist and facilitate both off-site propagation and on-site management of rare plants and plant communities. A seed orchard or nursery of rare species might be created, either at PBS, or on other local public school or park sites. Responsible public participation in the management and expansion of PBS biological communities for all of the purposes described above is highly advised.

11. UTILIZING GIS TO SUPPORT MANAGEMENT

The companion deliverables for this project are electronic data layers containing the plant community map and associated Federal Geographic Data Committee (FGDC) plant community classification (FGDC 1997), locations of protected species, locations of aquatic resources, and locations of recommended management areas. These data layers were produced in ARC/INFO J format. The data layers will be installed into the GIS that Stennis Space Center is developing for NASA GRC's Environmental Office. Color photographs of important plant communities and protected also are included in the data layers.

The data layers will be provided to natural resource managers so that they can view from a desktop computer all the spatial data for natural resources collected to date. The intent of this GIS is that it will be updated as additional information is collected or as site conditions change. Additional information should include new locations of protected species, management techniques that will be or have been implemented, the timing of management activities, tracking of burn areas and restoration plots, and any other information needed to effectively track protected species and the management of natural resources at the facilities.

Both sites support sensitive biological resources (rare plant and animal species and/or rare communities, ODNR 2002). The locations of these sensitive resources have been recorded and are represented on GIS data layers. These locations can be viewed with respect to the plant communities identified in this report to determine priority areas for conservation. Knowledge of these specific locations and the preferred habitat(s) as depicted in the plant community map will enable the development of a structured monitoring and management program as well as restoration programs, where appropriate.

The natural resource data layers also may be used to determine the usability of particular areas for future development. For example, all physiognomic formations with temporary or more frequent flooding (e.g., seasonal, semipermanently) contain potential jurisdictional wetlands. Proposed development areas that contain these habitats can be surveyed for jurisdictional wetlands and appropriate avoidance measures can be taken. In addition, knowledge of areas at the site that contain sensitive species or communities can be used in planning for development. Development can be structured to avoid these areas.

Other data layers such as Areas of Concern for chemical contamination can be overlain on the natural resource layers. Viewing the spatial data in this way will enable managers to determine threats and potential risks to protected species. The spatial data will facilitate site planning for and remedial activities or future development. Many other similar applications exist for the use of the spatial data.

12. SUMMARY

The report presents recommendations and general methodologies for managing protected species and rare plant communities at Lewis Field and PBS. NASA facilities are required to maintain current records of species protected by the Endangered Species Act. In addition, NASA facilities must develop programs for the management of any protected species and their critical habitat where

present on property managed by NASA. This is the third volume in a series of three reports that were prepared to assist with NASA complying with all applicable federal and state regulations with regards to endangered and threatened species. In addition, the reports address rare plant communities at the facilities. Volume I: Biological Surveys (ODNR 2002) contains current inventories of plant and animal species identified during the 2001 field season. Volume II: Plant Community Survey (SAIC 2002) contains descriptions and maps of plant communities and aquatic resources at the two facilities. Volume II is the companion text to the electronic GIS data layers developed for this project.

The goal of the protected species management strategy was to produce a management plan that contains current information on protected species and rare plant communities that will facilitate prioritization, planning, and implementation of specific management activities. The GIS data layers containing the current information are easily updated and will be integrated with other spatial data critical to the management of the facilities. The GIS data layers will become a component of the facility GISs developed by the Stennis Space Center.

Two general approaches to natural resource management are presented in this management plan. The first is a more holistic approach where management of entire plant communities is recommended. The second is a focused approach where management of individual species or groups of species requires additional activities not covered by the first approach. The combination of these approaches will ensure the preservation of protected species as well as the preservation and enhancement of natural plant communities at the two facilities.

PBS contains vast natural resources in the form of a complex mosaic of plant communities in various successional stages and hydrologic regimes. Much of PBS is undeveloped natural areas or recovering natural areas previously used for agriculture. The size and diversity of natural habitats at PBS supports a large number of plant and animal species (see ODNR 2002 and SAIC 2002). Many of these areas contain rare plants species and rare plant communities, including rare prairie species and remnant oak savannas.

At PBS, eight core sites containing areas of special vegetation significance were identified as priority areas for management. These include specific sites with identified populations of rare or state-listed plant species. They can be small and local, or somewhat extensive in area. But in all cases their distinguishing characteristic is that they support a growth of rare plants or can be restored to a condition that supports rare plants. The loss of the most important sites likely would mean the irretrievable loss of the local rare plants, many of which are exceptionally rare or state-listed and found nowhere else in the region or state.

Effective management will require the use of several techniques to control undesirable or overgrown plants, maintain existing native plants and plant communities, and restoring native plant communities. Historically, periodic landscape fires were important in controlling the distribution and abundance of species in the region. Prescribed burns are recommended to maintain and restore areas of native vegetation. Other measures include control the deer population and invasive non-native plants. Some protected or rare species require specific measure to address them. Aquatic

resources can be improved through the establishment of more wooded riparian corridors along streams, restoration of redwater ponds, and restoration/enhancement of wetlands.

Lewis Field is a much smaller facility in terms of land area compared to PBS, and proportionally it is much more developed. Although small, Lewis Field does contain some significant forest communities along Abram Creek. The primary threats to these forests are invasive plants such as Asian honeysuckles (*Lonicera* spp.) and future development. Efforts should be made to monitor and control invasive species and any development plans should seek to avoid these forested areas. Biota in Abram Creek will benefit from ongoing efforts at the adjacent airport to eliminate the release of de-icing compounds to surface water.

The management areas presented in this document should be viewed as core sites where management is most important or will be most effective. The delineation of these core sites is not intended to discourage management of other areas should available resources allow for more wide-spread active management. In addition, the core sites could be expanded in size if other land use considerations will allow larger properties to be managed specifically for rare species and plant communities. For example, the entire area between Columbus Avenue and East Patrol Road (except the main office building area) at PBS could be managed as a prairie/forest complex rather than just the core site labeled East Patrol Road Prairie Area. The establishment of management areas in the field should be based on the priorities presented in this document and the available NASA resources to implement the management recommendations.

In general, this report is intended to provide resource managers at NASA with the information and concepts needed to set priorities and establish specific plans to ensure the preservation rare species and communities that exist on NASA property. The recommendations suggest extensive active management at the PBS facility. Partnerships with other government agencies and conservation organizations should be considered to assist in this management.

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APPENDIX A

PHOTOGRAPHS OF AREAS OF SPECIAL VEGETATION SIGNIFICANCE

Photo 1. PBS - East Patrol Road Rare Prairie Plant Site showing *Helianthus mollis* (ashy sunflower) population

Photo 2. PBS - Magazine Area

Photo 3. PBS - Pentolite Area Native Forests

Photo 4. PBS - West Area Native Forests

Photo 5. PBS - South Patrol Road and Taft Road Savanna Areas

Photo 6. PBS - Pentolite Road Savanna Area

Photo 7. PBS - Central Meadows Area

Photo 8. PBS - Gateway Meadows Area

Photo 9. Lewis Field - Intact Native Forests - *Tsuga canadensis* - *Betula alleghaniensis* Forest Alliance

Photo 10. Lewis Field - Intact Native Forests - *Fagus grandifolia* - *Acer saccharum* - (*Liriodendron tulipifera*) Forest Alliance

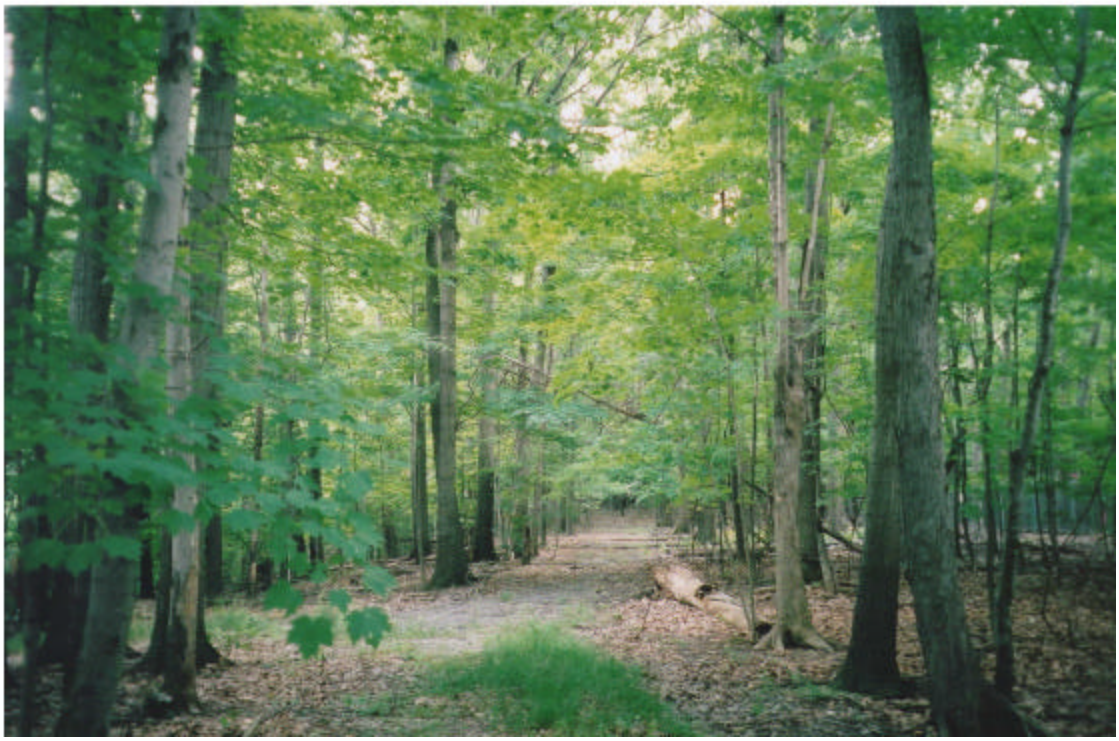

Photo 11. Lewis Field - Intact Native Forests - Quercus rubra – Acer saccharum – (Quercus alba) Forest Alliance

APPENDIX B

ODNR PROTECTION ZONES FOR BALD EAGLE NESTS

PROTECTION ZONES

Some activities close to a bald eagle nest may disturb the eagles when they are building their nests, sitting on eggs, and raising their young (Fig. 3). Other activities may change the habitat around the nest so that the eagles do not return to the nest the following year. On the following pages are recommendations for establishing Protection Zones around nest sites on your property. Three different Protection Zones are recommended for each nest site, and suggestions for ways you can avoid disturbing the eagles are listed. These Protection Zones should be established for nests currently being used and for alternate nest sites that have been used in the past three years.

Zone 1

Zone 1 is the area in which eagles are most sensitive to disturbance, and the greatest degree of protection is necessary. The boundary of this zone should be a minimum of 330 feet from the nest (Fig. 4).

Recommendations:

1. Year-round

These habitat changes should be prevented:
- Timber cutting of any kind
- Land clearing
- Building, road, or trail construction

2. February 1 to July 15

Unauthorized people should not be allowed in this zone. Foot traffic kept to an absolute minimum.

3. July 16 to August 15

Activity should be kept to a minimum.

Zone 2

Zone 2 covers an area in which the eagles are still sensitive to disturbance during the nesting season (February 1 to July 15), but less likely to be affected at other times of the year. The boundary of this zone should be a minimum of 660 feet from the nest (Fig. 4).

Recommendations

1. February 1 to July 15

Human activity should be kept to a minimum. Consult a wildlife manager.

2. July 16 to August 15

These activities are possible:
- Hunting
- Fishing
- Hiking
- Farming

3. August 16 to February 1

These activities are possible:
- Standard farming practices
- Maintenance of existing buildings and roads
- Hunting and trapping

Zone 3

Most activities are possible in Zone 3 outside of the breeding season. However, the management of this zone should include the protection of any bald eagle roosts or feeding sites in the area. The boundary of this zone should be a minimum of one-quarter mile from the nest (Fig. 4).

Recommendations

Activities in this zone that are within sight of the eagles on the nest may need to be conducted outside the breeding season. Consult a wildlife manager.

Management of roosts and feeding sites.

Protection zones

Mature live trees and dead trees necessary for perches and protection from the wind should be maintained in a zone 100 yards wide around each roost. This area should be closed to timber cutting and land clearing. Human activities within sight of the eagles should be restricted within 200 yards of the roost.

Shoreline

Land within 30 yards of the shoreline should be protected from timber cuts of one acre or more. As many dead trees as possible should be left standing, and trees with a diameter of 12 inches or greater left for use as perch trees. Recreational boating should be kept to a minimum within 100 yards of the shore, in areas identified as important feeding sites.

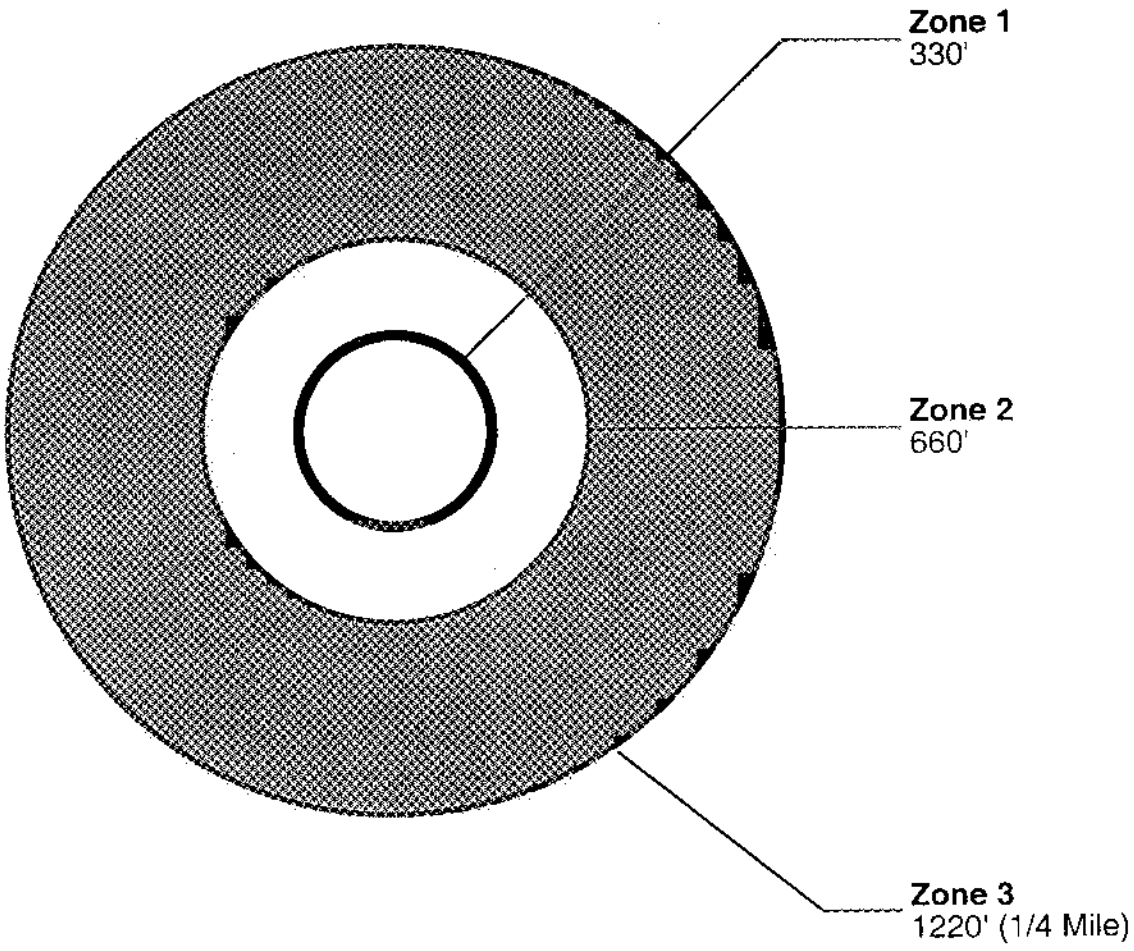

Fig. 4. Zones of protection for Ohio bald eagle nests.

APPENDIX C

ODNR LISTS AND FACT SHEETS OF INVASIVE NON-NATIVE PLANTS IN OHIO

Targeted Species	
Common Name	**Scientific Name**
Autumn olive (P, F)	*Elaeagnus umbellata*
Buckthorn, glossy (F)	*Rhamnus frangula*
Buckthorn, European (F)	*Rhamnus cathartica*
Garlic mustard (P, L, F)	*Alliaria petiolata*
Honeysuckle, Amur (P, F)	*Lonicera maackii*
Honeysuckle, Japanese (F)	*Lonicera japonica*
Honeysuckle, Morrow (P, L, F)	*Lonicera morrowii*
Honeysuckle, Tatarian (P, F)	*Lonicera tatarica*
Knotweed, Japanese (F)	*Polygonum cuspidatum*
Purple loosestrife (P, F)	*Lythrum salicaria*
Rose, multiflora (P, F)	*Rosa multiflora*
Giant reed grass (P, F)	*Phragmites australis*
Reed canary grass (P, F)	*Phalaris arundinacea*

P = Present at PBS
L = Present at Lewis Field
F = Fact sheet available from ODNR, Division of Natural Areas and Preserves

Well-Established Non-Natives	
Common Name	**Scientific Name**
Air-potato	*Dioscorea batatas*
Barberry, Japanese (P, L)	*Berberis thunbergii*
Bindweed, field (P)	*Convolvulus arvensis*
Bittersweet, Asian (F)	*Celastrus orbiculatus*
Bouncing bet (P)	*Saponaria officinalis*
Brome, smooth (P, F)	*Bromus inermis*
Burning bush	*Euonymus alatus*
Cat-tail, narrow-leaved (L, F)	*Typha angustifolia*
Celandine, lesser	*Ranunculus ficaria*
Crown-vetch (P, L)	*Coronilla varia*
Dame's rocket (P, L)	*Hesperis matronalis*
Day-lily	*Hemerocallis fulva*
European cranberry-bush	*Viburnum opulus var. opulus*
Fescue, meadow	*Festuca pratensis*
Flowering-rush	*Butomus umbellatus*
Johnson-grass	*Sorghum halpense*
Moneywort (P)	*Lysimachia nummularia*
Naiad, lesser (P, F)	*Najas minor*
Periwinkle (myrtle)	*Vinca minor*
Poison hemlock (P)	*Conium maculatum*
Pondweed, curly (F)	*Potamogeton crispus*
Privet, common (P)	*Ligustrum vulgare*
Quack grass	*Agropyron repens*
Queen Anne's lace (P, L)	*Daucus carota*
Russian olive (F)	*Elaeagnus angustifolia*
Sweet-clover, white (P, F)	*Melilotus alba*
Sweet-clover, yellow (P, L, F)	*Melilotus officinalis*
Teasel, common (P, L, F)	*Dipsacus sylvestris (D. fullonum)*
Teasel, cut-leaved (F)	*Dipsacus laciniatus*
Thistle, Canada (P, L, F)	*Cirsium arvense*
Tree-of-heaven (P, F)	*Ailanthus altissima*
Watermilfoil, Eurasian (F)	*Myriophyllum spicatum*
Willow-herb, hairy	*Epilobium hirsutum*
Wintercreeper	*Euonymus fortunei*
Yellow flag	*Iris pseudoacorus*

P = Present at PBS
L = Present at Lewis Field
F = Fact sheet available from ODNR, Division of Natural Areas and Preserves

Watch List Species	
Common Name	**Scientific Name**
Black swallow-wort	*Vincetoxicum nigrum*
Cat-tail hybrid (F)	*Typha x glauca*
Dog rose (L)	*Rosa canina*
Honeysuckle, showy pink	*Lonicera x bella*
Knapweed, spotted (L)	*Centaurea maculosa*
Kudzu	*Pueraria lobata*
Mile-a-minute	*Polygonum perfoliatum*
Small-flowered hairy willow herb	*Epilobium parviflorum*
Spurge, leafy	*Euphorbia esula*
Water-cress	*Rorippa nasturtium-aquaticum*

P = Present at PBS
L = Present at Lewis Field
F = Fact sheet available from ODNR, Division of Natural Areas and Preserves

INVASIVE PLANTS OF OHIO

Approximately one-fourth of the plant species known to occur in Ohio originate from other parts of the continent or the world. These species are commonly called non-native, exotic or alien because they were not known from Ohio prior to the time of substantial European settlement around 1750. Since these species are not native to Ohio, they lack the natural predators and diseases which control them in their native habitats. They are usually characterized by fast growth rates, high fruit production, rapid vegetative spread, and efficient seed dispersal and germination. They often tolerate a wide range of environmental conditions and are quick to colonize recently disturbed sites. Some of Ohio's non-native plants arrived here by accident, while others were introduced for agriculture, erosion control, horticulture, forage crops, medicinal use, and food for wildlife. Some of these invasive non-native plants are commercially available, primarily as cultivars.

Most non-native plant species are not invasive in natural areas. Of the more than 700 non-native plants in Ohio, fewer than 100 are known to be problems in natural areas. These fact sheets describe the most invasive non-native plant species which impact and degrade Ohio's woodlands, wetlands, prairies and other natural areas. These species threaten Ohio's native biological diversity by displacing native plant species altering the food web and displacing the wildlife that relies on native plants for food, shelter, and breeding sites.

Successful control of invasive plant species is a time, labor, and resource-intensive process. Prevention or control during the early stages of invasion is the best strategy. In areas where invasive plants are well established, multiple control strategies and follow-up treatments may be necessary. Specific treatment depends on the target species' biological characteristics and population size. Invasive plants can be controlled using biological, mechanical, or chemical methods. Biological control uses the natural enemies of the invasive plant species to reduce its population. This method requires research and experimentation before appropriate control agents can be released. For example, years of research were conducted before beetle and weevil species native to Europe were introduced in the Midwest to control purple loosestrife.

Mechanical control includes physical removal such as cutting, mowing, grazing, digging, or pulling plants. Some invasive species will quickly re-establish from root fragments, seed banks, or after extensive soil disturbance. Other mechanical controls imitate natural processes, such as altering water levels and prescribed burning. Manipulating water levels to control certain invasive wetland plants can work, but it may also harm non-target species or native communities. Prescribed fire is used by land managers in fire-adapted ecosystems. However, due to hazards and legal liabilities, prescribed fire is subject to federal, state and local regulations and may be difficult for private landowners to implement.

When other control methods are ineffective, the use of herbicides may often be the best recommendation. Systemic herbicides are frequently used to control invasive plants. They are applied to the above-ground part of the plant and are transported throughout the plant to the root system. Selective application methods include foliar spray or wicking, cut stump application, and basal bark application to standing shrubs and trees. Each technique minimizes the amount of herbicide used and strives to treat only the target plants, which is critical in natural areas. Depending on the herbicide used, cut stump and basal bark treatments can be used in the dormant season which reduces vegetation trampling. Foliar spray is done during the growing season, or occasionally on semi-evergreen or biennial rosettes when other species are still dormant but the temperature permits active photosynthesis.

Site characteristics, including soil types, surface and ground water, non-target vegetation, sensitive areas, and off-target exposure should be considered before applying herbicides. The timing of application, including the season, weather conditions, and growth stage of the target species should also be considered. To be most effective, many herbicides require penetrating, wetting, or sticking agents (such as Penevator Basal Oil® or Nu-Film-P®). Other factors to evaluate before choosing a herbicide include: the type and concentration of active ingredients, its toxicity and health effects, selectivity (whether it harms all plants or only certain kinds), how long it persists in the environment, whether it moves off target (through the roots, spray drift, or vapor), and whether it can be used over or near water. Only certain herbicides are approved for wetlands or aquatic habitats. The herbicide label provides most of this information. Land managers experienced in herbicide use are also valuable sources of information.

The herbicides named in these fact sheets are referenced by product brand names. This does not imply an endorsement of a particular manufacturer's product, but these names are more recognizable than the active ingredient. Label instructions should be followed carefully. Persons who apply herbicides for hire are required by Ohio law to be licensed by the Ohio Department of Agriculture, Division of Plant Industry. On public lands, only licensed applicators or trained servicemen, under the supervision of a licensed applicator, may apply herbicides. Some herbicides are classified as "restricted use" and require a license for purchase and use.

After intensive removal of invasive species, restoration of natural habitats through replanting with native species is often needed. Nurseries and horticultural professionals can assist with native plant restoration. Complete eradication of invasive non-native plants from a site may not be completely achieved, but it is possible to reduce infestations within native plant communities to a level which can be routinely maintained. Control of invasive plants is critical to the long-term protection of Ohio's natural areas and rare species.

Additional Information Sources:

Hoffman, R. and K. Kearns, eds. 1997. Wisconsin Manual of Control Recommendations for Ecologically Invasive Plants. Bureau of Endangered Resources, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

Illinois Nature Preserves Commission. 1990. Illinois Vegetation Management Manual. Vegetation Management Guidelines.

Ohio State University Extension. 1992. Applying Pesticides Correctly: A Guide for Private and Commercial Applicators. Bulletin 825. The Ohio State University Extension, Columbus, Ohio.

Ohio Department of Agriculture, Division of Plant Industry, 8995 East Main Street, Reynoldsburg, Ohio 43068-3399. (614) 728-6987.

Tennessee Exotic Pest Plant Council. 1996. Tennessee Exotic Plant Management Manual.

Virginia Department of Conservation and Recreation & Virginia Native Plant Society. Invasive Alien Plant Species of Virginia.

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INVASIVE PLANTS OF OHIO

Fact Sheet 1

Amur, Morrow & Tatarian Honeysuckle

Lonicera maackii, L. morrowii, L. tatarica

Amur Honeysuckle Division Photo

DESCRIPTION:

Amur, Morrow and Tatarian honeysuckles are non-native, upright, deciduous shrubs that grow to be 6-15 feet tall. The best way to distinguish these three species are by their leaves and flowers/fruits. Amur honeysuckle has dark green leaves that end in a sharp point at the tip and the underside of the leaf has hair along the veins. Morrow and Tatarian both have oval, egg-shaped leaves. By contrast, the leaf of Tatarian honeysuckle lacks hair on the underside, while Morrow is consistently hairy on the underside. Amur and Morrow both have white, paired flowers that turn yellow with age while Tatarian is pale pink. The flower peduncles (stems) are also descriptive: Amur has very short, pubescent peduncles (2-4mm), Morrow's are long and pubescent (10-12mm), and Tatarian's are long and glabrous (10-15mm) and all three exhibit a hollow stem in cross-section which can be used to distinguish them from some native honeysuckles. The fruits are yellow to dark-red berries. Showy pink honeysuckle (*L.* x*bella*) is an invasive hybrid of Morrow and Tatarian honeysuckle with showy pink flowers. Shrub bush-honeysuckle (*Diervilla lonicera*) is native to Ohio and can be distinguished from these non-native species by the solid pith of the stem and yellow to reddish flowers.

HABITAT:

These bush honeysuckles are adaptable to a wide range of habitats. They are most commonly found in the understory of woodlands as well as the edges of marshes.

Morrow Honeysuckle Division Photo

Tatarian Honeysuckle Division Photo

DISTRIBUTION:

Amur, Morrow and Tatarian honeysuckles are native to China, Korea and Japan. Introduced into the United States in 1846 as ornamental plants, they have escaped cultivation due to high seed production and to the fact their seeds are readily eaten and dispersed by birds. These honeysuckles are distributed throughout Ohio with Amur being more problematic in southwestern Ohio, Morrow in northern Ohio, and Tatarian throughout the state.

PROBLEM:

These vigorous shrubs shade out native vegetation, particularly in the woodland understory. They are able to out-compete native wildflowers for light and other resources. Bush honeysuckles green up earlier in the spring than most other plants, giving them an advantage over other species. Each produces abundant amounts of seed which are spread by birds and other animals.

Amur Honeysuckle Division Photo

CONTROL:

Mechanical: The bush honeysuckles in less dense populations can be pulled, making sure that all the roots have been removed. Any remaining roots in the ground are likely to re-sprout. A pulaski, Weed Wrench, or other similar tool may be used to remove the plant from the ground.

Chemical: For more dense populations, systemic herbicides, such as Roundup®, Glypro®, Garlon 3A®, and Garlon 4®, are the most effective control. The best methods of application are foliar spray for large populations when there are no desirable species in the vicinity, cut stump treatment for areas with desirable non-target species, and basal bark applications which are effective throughout the year whenever the ground is not frozen. Foliar application should only be used when the outside temperature is above 65° F to allow for complete absorption of the chemical. It may also be applied to re-sprouts after cutting. Cut stump treatment with Garlon 4® can be applied year-round as long as the ground is not frozen.

Biological: There are currently no biological control methods for these honeysuckles.

ADDITIONAL INFORMATION SOURCES:

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Tennessee Exotic Plant Management Manual. Tennessee Exotic Pest Plant Council.

Converse, Carmen K. 1984. Element Stewardship Abstract for *Lonicera* spp., Bushy Honeysuckles. The Nature Conservancy.

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INVASIVE PLANTS OF OHIO

Fact Sheet 2

Glossy Buckthorn & Common Buckthorn

Rhamnus frangula, R. cathartica

DESCRIPTION:

Glossy Buckthorn John Watts

Both glossy buckthorn and common buckthorn are non-native woody shrubs or small trees that can reach up to 20 feet in height. Cutting the stems of either species reveals a distinctive yellow sapwood and pink to orange heartwood. Glossy buckthorn has gray-brown bark and lightly colored lenticels which give the bark a speckled appearance. Leaves of glossy buckthorn are entire, 1-3 inches long, shiny on the upper surface, oval shaped and slightly wavy. Flowers are 5-petaled, greenish-white and the fruits are red, turning purplish-black when ripe. Plants flower from late May until the first frost and fruits ripen from early July to September. Common buckthorn has smooth, deeply veined, oval leaves (1-2½ inches long) with toothed margins. Common buckthorn is a dioecious species with male and female flowers on separate plants. Flowers are 4-petaled and yellow-green in color; fruits are black. Flowering takes place from May through June and fruits ripen from August to September. Twigs of common buckthorn are often tipped with short spines. A native species, Carolina buckthorn (*Rhamnus caroliniana*), also occurs in Ohio.

HABITAT:

Glossy buckthorn typically invades wetlands including swamps, bogs, fens and wet meadows but also occurs in upland habitats such as woodland edges, old fields and roadsides. Common buckthorn is primarily an invader of upland sites including open woods, woodland edges, prairies and open fields. Both species are capable of growing in full sun as well as heavily shaded areas.

Common Buckthorn Division Photo

DISTRIBUTION:

Glossy buckthorn and common buckthorn were introduced to North America from Eurasia as ornamental shrubs for fence rows and wildlife habitat and are still used in landscaping. These species are distributed throughout the northeast and north central U.S. Both species are frequent in the central and northern part of the state.

PROBLEM:

Both glossy and common buckthorn have a wide habitat tolerance, rapid growth rates and extensive root systems. Both species produce abundant flowers and fruits throughout the growing season. Seeds are widely dispersed by birds. Once established, these species aggressively invade natural areas and form dense thickets displacing native species. They leaf out very early in the growing season and keep their leaves late into the fall helping to shade out native trees, shrubs and wildflowers.

CONTROL:

Mechanical: Prescribed burning has been used to control buckthorns in some natural areas. Fire will top kill stems, however re-sprouting will occur and seed germination may increase. Several years of burning may be necessary to control these species and may not be appropriate in some natural areas. Hand pulling may be successful in small infestations, although several seasons may be required as re-sprouting will occur if part of the root is left behind. This method also disturbs the soil, increasing seed germination. Repeated mowing has been reported effective in maintaining open areas and preventing seedling establishment.

Chemical: Control of buckthorns with systemic herbicides has been successful in many situations. Application of Roundup®, Accord®, Glypro® or Garlon 4® to cut stumps during the growing season and in warm days of winter has proven to be effective. Other application methods may include basal bark and foliar application. A foliar application of Garlon 3A® in dense thickets may be very effective in the spring and fall. Without treatment, stems will re-sprout vigorously after cutting due to the extensive root system.

Biological: Biological controls are not available, however studies of possible fungal and insect pests are ongoing.

ADDITIONAL INFORMATION SOURCES:

Converse, C.K. 1999. Element Stewardship Abstract for *Rhamnus cathartica, Rhamnus frangula*. The Nature Conservancy.

Reinartz, J.A. 1997. Controlling glossy buckthorn (*Rhamnus frangula* L.) with winter herbicide treatments of cut stumps. Natural Areas Journal 17(1): 38-41.

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INVASIVE PLANTS OF OHIO

Fact Sheet 3

Garlic Mustard

Alliaria petiolata

DESCRIPTION:

John Watts

Garlic mustard is a non-native, biennial herb that grows 5-46 inches tall. The first-year plant is in the form of a rosette with kidney-shaped leaves that remain green throughout the winter. The second year, a flowering stem is produced with triangular-shaped leaves that are sharply toothed. Crushed leaves emit a garlic-like odor. The flowers bloom in a cluster at the end of the stem. Each small flower has four white petals and blooms from May to June. The fruits are long, green capsules that become brown as the seeds mature, making it easy to identify.

HABITAT:

Garlic mustard generally prefers some shade and can be found in upland and flood plain forests, savannas, yards, along roadsides, and occasionally in full sun. This plant invades forests first at the edge, then progresses to the interior along streams and trails.

Division Photo

DISTRIBUTION:

Garlic mustard originated in Europe and was introduced to the United States for herbal and medicinal puroses. It was first recorded in the United States in 1868 in Long Island, New York. By 1991, garlic mustard had invaded 28 Midwestern and northeastern states. Garlic mustard can be found throughout the state of Ohio.

PROBLEM:

Garlic mustard aggressively out-competes native species in the understory of forests and woodlands. This plant begins growth in early spring and ends growth later in the season than most native species. As a result, garlic mustard shades out native wildflowers and out-competes native seedlings. Garlic mustard grows in dense clusters and can displace most herbaceous native plants within 10 years. Large quantities of seed are produced and can remain viable in the soil for up to 7 years. The seeds are dispersed by wind, water and transported by animals and humans.

CONTROL:

Mechanical: Mechanical controls of garlic mustard include hand-pulling and cutting, and are most effective on smaller infestations. Hand-pulling of plants can be very effective, although labor intensive. Care must be taken to insure that the entire plant is removed and that all plant materials are bagged and moved off-site. A plant can continue to mature and produce seeds even if it has been pulled up. Hand-pulling and removal must continue until the seed bank is exhausted (at least 7 years). Cutting populations of garlic mustard is effective for medium to large concentrations of plants. Stems may be cut by mowing, brush-cutting, or by hand when the plants are in flower. This can result in total mortality of the plants, however it does not affect the seed bank. Cutting must continue every year until the seed bank is exhausted. Prescribed fire can be an effective control agent in controlling garlic mustard given the proper location and fire intensity. Repeated, effective burns over several years are necessary.

Chemical: Foliar application of herbicide can be used to control populations of garlic mustard where mechanical methods may not be effective, such as large infestations. Roundup® or Glypro® are effective herbicides to use, however they are not selective so non-target species in the vicinity of the application may be affected. Herbicide should be applied to the first year rosettes during the late fall and early spring when non-target species are dormant.

Biological: Currently there are no programs in use, however research is being conducted to find a potential biological control agent.

ADDITIONAL INFORMATION SOURCES:

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Tennessee Exotic Plant Management Manual. Tennessee Exotic Pest Plant Council.

Nuzzo, V. 1994. Element Stewardship Abstract for *Alliaria petiolata*, Garlic Mustard. The Nature Conservancy.

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INVASIVE PLANTS OF OHIO

Fact Sheet 4

Purple Loosestrife

Lythrum salicaria

DESCRIPTION:

Division Photo

Purple loosestrife is a dense, herbaceous, non-native perennial that grows up to 7 feet tall. With attractive purple to magenta flowers, purple loosestrife cultivars are a popular ornamental. The flowers bloom in long spikes with 1-50 square stems per plant. One plant can produce over 100,000 seeds. The linear green leaves are opposite along the stem. This plant has a woody taproot and fibrous rhizomes that form a thick mat. Purple loosestrife is similar to the native loosestrife *Lythrum alatum*, however, *L. alatum* has alternate leaves on the upper stem, wider spaced flowers and is smaller in size. Looking closely at both flowers *L. salicaria* has 12 stamens and *L. alatum* has 4-6 stamens. Currently in Ohio, *Lythrum salicaria* is illegal to sell. However, commercially available cultivars like *L. virgatum* can cross pollinate with wild populations of purple loosestrife and produce viable seed.

HABITAT:

Purple loosestrife occurs mostly in wetland environments, but when well established, it can survive drier conditions. Wetlands impacted by this plant include marshes, fens, wet meadows, stream and river banks, and lake shores.

DISTRIBUTION:

Purple loosestrife was introduced to North America from Europe and Asia in the early 1800s as a contaminant in ship ballast, as well as a medicinal herb and garden plant. It escaped and became a pioneer species of newly constructed waterways and canals. Purple loosestrife occurs throughout the United States with its heaviest concentrations in the northeast. Although *Lythrum salicaria* is currently no longer available to purchase, cultivars continue to be distributed. In Ohio, this plant can be found throughout the state, although it is more established in the northern half.

Division Photo

PROBLEM:

Purple loosestrife adapts readily to natural and disturbed wetlands. As it establishes and expands, it out-competes and replaces native grasses, sedges, and other flowering plants that provide a higher quality source of nutrition for wildlife. Purple loosestrife forms dense, homogeneous stands that restrict native wetland plant species and reduces habitat for waterfowl. Seed production is as prolific as the vegetative growth. Seeds are widely distributed by animals, machinery and people and in waterways.

CONTROL:

Mechanical: Small infestations of purple loosestrife can be removed by hand. The entire root system must be removed from the ground. All plant material should be bagged and removed from the area to eliminate re-sprouting. Larger populations are harder to control using mechanical means. Mowing should not be used because it can increase the spread of the population by dispersing seeds and exposing the seed bank.

Chemical: Herbicides can be used effectively to control small populations of purple loosestrife. Only herbicides permitted for wetland use, such as Accord® or Glypro®, may be used. By eliminating all the plants in an area, the soil is exposed for the immense purple loosestrife seed bank to germinate. Spot application of herbicide can help limit this problem. The most species specific way to apply herbicide is by cutting and treating the stems. Foliar spray can be used by applying herbicide after the period of peak bloom, in late August. Any control method should be followed up on a yearly basis to catch any missed plants or new sprouts. Certain broadleaf specific herbicides, such as Garlon 3A®, which do not harm monocot species (grasses and sedges) that typically occur in wetlands, can also be used.

Biological: Several species of insects are being studied for their effectiveness in the control of purple loosestrife. A species of weevil (*Hylobius transversovittatus*) lays eggs in the stem and upper root system of the plant and as the larvae develop, they feed on root tissue. Two species of leaf-eating beetles (*Galerucella calmeriensis* and *G. pusilla*) and a weevil (*Nanophyes marmoratus*) that feeds on flowers and stresses the plant are being released into areas of high purple loosestrife density and are being monitored. Since 1994, the Ohio Division of Wildlife has introduced these insects into 13 areas. Although this method will not eradicate the species, it may create a more tolerable population level that will stabilize over time.

ADDITIONAL INFORMATION SOURCES:

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Tennessee Exotic Plant Management Manual. Tennessee Exotic Pest Plant Council.

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Hoffman, R. and K. Kearns, eds. 1997. Wisconsin Manual of Control Recommendations for Ecologically Invasive Plants. Bureau of Endangered Resources, Wisconsin Department of Natural Resources.

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INVASIVE PLANTS OF OHIO

Fact Sheet 5

Common Reed Grass

Phragmites australis

Division Photo

DESCRIPTION:

Common reed grass is a tall, invasive perennial wetland grass ranging in height from 3-15 feet. The plant produces horizontal rhizomes that grow on or beneath the ground and produce roots and vertical stalks (culms). The rhizomes allow the plant to form large colonies. The stiff, hollow stalks support leaf blades which are smooth, broad and flat (1½ - 2 inches wide). A large terminal inflorescence (panicle) is produced in late June and is purplish in flower and grayish in fruit. Large quantities of seed are produced, however, most or all of the seed may not be viable.

HABITAT:

Common reed grass is prevalent in open wetland habitats and favors alkaline and brackish waters. These areas include drier borders and elevated areas of brackish and freshwater marshes, along riverbanks and lake shores and almost anywhere there are slight depressions that hold moisture. The species is particularly frequent in disturbed or polluted soils along roadsides, ditches and dredged areas. It is also known to tolerate highly acidic conditions.

DISTRIBUTION:

Some populations of common reed grass are more invasive than others and may be non-native. It is suspected that the non-native, aggressive strain of common reed grass was introduced to North America in the early 20th century. It can now be found throughout the United States. In Ohio, this strain is primarily found in the northern part of the state, however it has recently progressed south.

PROBLEM:

Common reed grass can be considered a natural component of some undisturbed wetlands. However, the invasive strain grows aggressively in areas that are disturbed or stressed by pollution, dredging or other alteration of the natural hydrologic regime. Invasive stands of common reed grass eliminate diverse wetland plant communities, providing little food or shelter for wildlife.

Division Photo

CONTROL:

Mechanical: Cutting, pulling or mowing can be done in late July and should be repeated for several years. All cut shoots should be carefully removed to prevent re-sprouting. The placement of black plastic over cut stems has had some success and burning in combination with herbicide application has also been effective in some situations. Hydrologic controls such as flooding for an extended period during the growing season may also be successful.

Chemical: Herbicide application with Accord®, Rodeo® or Glypro® is most effective in the early fall, after tasseling, and should be applied at least two years in a row. Fusilade DX®, a grass specific herbicide can be applied in non-aquatic areas. Methods of application will depend on the associated plant community but may include aerial spraying, hand-held or backpack sprayers and hand-wicking.

Biological: No biological controls are known at this time.

ADDITIONAL INFORMATION SOURCES:

Marks, M., B. Lapin and J. Randall. 1994. *Phragmites australis* (*P. communis*): Threats, Management and Monitoring. Natural Areas Journal 14(4): 285-294.

Randall, J. 1993. Element Stewardship Abstract for *Phragmites australis*. The Nature Conservancy.

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INVASIVE PLANTS OF OHIO

Fact Sheet 6

Reed Canary Grass

Phalaris arundinacea

DESCRIPTION:

Reed canary grass is a 2-9 foot tall, non-native grass with flat, rough-textured, tapering leaves from 3½-10 inches long. The stem is hairless and stands erect. One of the first grasses to sprout in the spring, reed canary grass produces a compact panicle 3-16 inches long that is erect or slightly spreading. The flowers are green to purple early in the season and change to beige over time. This grass forms a thick rhizome system that quickly dominates the soil. There is some debate as to the origin of the species. Sources document native and non-native genotypes of reed canary grass. The non-native strain is thought to be more invasive than the native strain.

HABITAT:

Reed canary grass occurs in wetlands such as marshes, wet prairies, wet meadows, fens and stream banks. This grass quickly dominates areas of wet, exposed soils and can also grow in areas of standing water by producing special roots off the submersed portion of the stem. Reed canary grass can also grow on dry soils in upland sites and under partial shade; however, it does best in full sun and moist soils.

DISTRIBUTION:

The non-native strain of reed canary grass was introduced from Europe and Asia in the early 1800s. It was selected for its vigor as a forage crop and erosion control. In Ohio, reed canary grass is widespread throughout the state.

PROBLEM:

Reed canary grass reproduces vegetatively as well as by seed. It aggressively dominates an area and displaces the native vegetation replacing it with a monoculture of grass. This species of grass produces little in the form of shelter and food for wildlife, although it has been used for bank stabilization in wetlands and waterways. Seeds are easily dispersed by means of waterways, animals and people.

Division Photo

Division Photo

CONTROL:

Mechanical: In smaller patches, hand-pulling or digging may be effective. Mowing can be used to control seed production by mowing in early to mid-June and early October before seed matures. This also exposes the soil to light which will promote the growth of other species. Discing or plowing can also be used to control a well-established population. Although prescribed burning can be effective, it must be repeated annually for 5 or 6 years. Timing may be difficult due to fluctuating water levels and the growth stage of the plants at burn time. A combination of these measures used together may improve results.

Chemical: Herbicides, such as Accord® or Glypro®, can be applied to control reed canary grass. Fusilade DX®, a grass specific herbicide, can be applied in non-wetland areas. Herbicide should be applied in early spring when non-target species are still dormant. Removal of the previous year's growth to expose the new green shoots aids effectiveness of the chemical and minimizes the amount needed. Foliar application of Glypro® to larger monocultures of reed canary grass can be effective. Chemical treatments following mowing in the fall season can help control this grass as well.

Biological: There are currently no biological control methods in use for reed canary grass.

ADDITIONAL INFORMATION SOURCES:

Hoffman, R. and K. Kearns, eds. 1997. Wisconsin Manual of Control Recommendations for Ecologically Invasive Plants. Bureau of Endangered Resources, Wisconsin Department of Natural Resources.

Hutchison, M. 1990. Vegetation Management Guideline: Reed canary grass (*Phalaris arundinacea*). Illinois Nature Preserves Commission.

Lyons, K.E. 2000. Element Stewardship Abstract for *Phalaris arundinacea*. The Nature Conservancy.

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INVASIVE PLANTS OF OHIO

Fact Sheet 7

Autumn-Olive and Russian-Olive

Elaeagnus umbellata, E. angustifolia

DESCRIPTION:

Autumn-olive and Russian-olive are non-native, deciduous shrubs or small trees that grow to 20 feet tall. The leaves on autumn-olive are small, oval, untoothed and dark green. It has small, light-yellow fragrant flowers in May-June and small round juicy fruits that are reddish to pink in color and dotted with silver or brown scales. Russian-olive's leaves are narrower and longer, and dull green. It has yellow flowers and dry yellow mealy fruits. Silver scales occur on the underside of the leaves of both species. The twigs of Russian-olive are typically covered with thorns. These shrubs begin to flower and fruit annually after 3 years. An individual plant can produce 8 pounds of fruit each year.

HABITAT:

Autumn-olive and Russian-olive have nitrogen-fixing root nodules which allows them to adapt to many poor soil types. They are found in areas such as pastures and fields, grasslands and sparse woodlands.

DISTRIBUTION:

Autumn-olive is native to China and Japan. It was introduced to the United States in 1830 and is distributed throughout the state. Russian-olive is originally from Europe and Asia. It was introduced to North America in the early 1900s and is found throughout Ohio. Historically these plants have been used for erosion control, strip mine reclamation, wildlife habitat, and in landscaping.

PROBLEM:

Autumn-olive and Russian-olive aggressively out-compete native plants and shrubs. They grow rapidly and re-sprout heavily after cutting or burning. Both species are prolific fruit producers, with seed dispersal mostly accomplished by birds.

Autumn-olive Division Photo

CONTROL:

Mechanical: Hand-pulling seedlings and sprouts is effective in the early spring when the ground is moist and the entire plant and root system can be removed. Other forms of control, such as mowing and burning, without the application of a herbicide usually contribute to a larger number of root sprouts.

Chemical: Systemic herbicides, such as Roundup®, Glypro®, Garlon 3A®, and Garlon 4® can be used effectively when applied to cut stumps or when used as a foliar spray. A small amount of Tordon K® in the mixture will control resprouting. Basal bark application of Garlon 4® with Penevator Basal Oil® can also be an effective form of control.

Biological: Currently there are no biological controls for Autumn-olive or Russian-olive.

ADDITIONAL INFORMATION SOURCES:

Virginia Department of Conservation and Recreation & Virginia Native Plant Society. Invasive Alien Plant Species of Virginia: Autumn-olive (*Elaeagnus umbellata* Thunberg) and Russian-olive (*Elaeagnus angustifolia* L.).

Sather, N. and N. Eckardt. 1987. Element Stewardship Abstract for *Elaeagnus umbellata*, Autumn-olive. The Nature Conservancy.

Szafoni, B. 1990. Vegetation Management Guideline: Autumn-olive (*Elaeagnus umbellata* Thunb.) Illinois Nature Preserves Commission.

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FS7CM

INVASIVE PLANTS OF OHIO

Fact Sheet 8

Multiflora Rose

Rosa multiflora

John Watts

DESCRIPTION:

Multiflora rose is a thorny, non-native perennial shrub with arching branches that can form dense thickets. Its compound leaves grow alternately and consist of 5-11 sharply toothed, oval leaflets. The stipules at the base of the leaf are feathery and characteristic of this plant. Multiflora rose produces many clusters of 1 inch-wide, white flowers in the late spring. Small, bright red fruits (rose hips) develop during the summer and remain on the plant throughout the winter.

HABITAT:

Multiflora rose prefers sunny areas and well-drained soils, but can tolerate a wide range of habitats. This plant readily invades open woodlands, forest edges, successional fields, savannas and prairies. Once established, multiflora rose grows rapidly forming dense, impenetrable thickets.

DISTRIBUTION:

Multiflora rose was introduced from Japan, Korea and eastern China in the 1860s as rootstock for ornamental roses. In the 1930s, it was widely promoted as a "living fence" for soil conservation and in wildlife programs. It is found throughout the United States with the exception of the Rocky Mountains, southeastern coastal plains and western desert areas. In Ohio, multiflora rose has a widespread distribution in pastures, woodlots and non-crop lands.

Division Photo

PROBLEM:

Thickets of multiflora rose can successfully displace native plant species. Multiflora rose reproduces from seed and by rooting from the arching stems. It has been estimated that an average plant produces a million seeds per year, which may remain viable in the soil for up to twenty years.

CONTROL:

Mechanical: Light multiflora rose infestations can be eradicated using a shovel, provided the entire root system is removed. For control of more severe invasions, mowing or cutting several times per growing season for 2-4 years can be effective. In some situations, a prescribed burn during the early growing season may be an appropriate method for controlling severe infestations.

Chemical: Applying systemic herbicides, such as Roundup®, Glypro®, or Garlon 4® directly to fresh cut stumps or as a basal bark application is the most effective control method. Roundup®, Glypro®, or Garlon 3A® may also be applied to the foliage.

Biological: Rose rosette disease, a natural pest on multiflora rose, was first found Ohio in 1987. Symptoms include red and purplish vein mosaics and dwarfed foliage. A virus is transmitted by a tiny mite and on average plants die within two years of infection. Efforts to introduce the disease into uninfected areas have proven difficult, but research in the area of additional biological control is ongoing and may provide a more promising control agent.

ADDITIONAL INFORMATION SOURCES:

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Tennessee Exotic Plant Management Manual. Tennessee Exotic Pest Plant Council.

Evans, J. and N. Ekhardt. 1987. Element Stewardship Abstract for *Rosa multiflora*. The Nature Conservancy.

Underwood, J.F. and E.W. Stroube. 1986. Multiflora Rose Control. Ohio Cooperative Extension Service, The Ohio State University.

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FS8SS

INVASIVE PLANTS OF OHIO

Fact Sheet 9

Japanese Honeysuckle & Asian Bittersweet

Lonicera japonica, Celastrus orbiculatus

Japanese Honeysuckle Division Photo

DESCRIPTION:

Both Japanese honeysuckle and Asian bittersweet are non-native, fast-growing trailing or climbing woody vines capable of covering large areas of ground or extending into the tops of trees. Japanese honeysuckle has entire, oval-oblong, opposite leaves from 1½ -3 inches long. In Ohio, the leaves are semi-evergreen, persisting late into winter or early spring. The stems are usually hairy and hollow inside, reaching a length of 30 feet or more. A profusion of 2-lipped, very fragrant, white to yellow flowers is produced in pairs in the leaf axils along the stems from April through June. The fruit is a many-seeded, black, pulpy berry maturing from September to November. Native honeysuckle vines (*L. dioica*) differ in that they bear red fruit at the ends of stems and the upper leaves of the stem are joined together. Asian bittersweet has finely-toothed, rounded, alternate leaves up to 4 inches long. The stems are round, often with noticeable lenticels, and may reach a length of 60 feet. Asian bittersweet produces numerous 5-petaled, greenish flowers that arise from the leaf axils. The fruit is a conspicuous, yellow, 3-valved capsule that splits open to reveal 3 bright orange-red seeds. The native bittersweet (*C. scandens*) can be distinguished by its elliptical shaped leaves and its flowers and fruits that arise at the tips of stems.

HABITAT:

Both Japanese honeysuckle and Asian bittersweet thrive in disturbed areas such as roadsides, fence rows, abandoned home sites and forest gaps caused by windfalls and logging. Areas of special concern are woodland edges, early successional forests, and riparian corridors. Although preferring sunny areas, both are shade-tolerant and can live in marginal habitats until favorable conditions arise.

DISTRIBUTION:

Japanese honeysuckle is native to eastern Asia and was introduced into New York in 1806 as an ornamental plant and ground cover. Now distributed over most of the southern and eastern United States, it is often planted as a source of food for wildlife. Asian bittersweet is also native to eastern Asia and was introduced into the United States in 1860 for ornamental purposes, for which it is still used in many areas. Having escaped from cultivation, it can be found over much of the eastern Midwest and Atlantic coast states. Both species are found throughout Ohio but seem to be more prevelant in the southern part of the state.

Asian Bittersweet Division Photo

PROBLEM:

Japanese honeysuckle and Asian bittersweet are aggressive growers that can severely damage native plant populations by limiting needed sunlight, constricting nutrient flow in stems, and over-weighting treetops increasing the likelihood of wind damage. Both are prolific seed producers with the seeds often being dispersed by birds. The root systems are very persistent and capable of extensive root suckering. Plants tend to regenerate quickly after cutting. These vines are often able to out-compete native species for nutrients and water.

CONTROL:

Mechanical: Hand-pulling with complete root removal is effective in small populations of both Japanese honeysuckle and Asian bittersweet. Mowing may also be effective in reducing the size of the plants, but often encourages extensive root suckering. Japanese honeysuckle may be controlled with prescribed burning.

Chemical: Chemical control of Japanese honeysuckle and Asian bittersweet may be attained using systemic herbicides such as Roundup®, Glypro®, Garlon 3A®, or Garlon 4® on cut stems or as a foliar spray. For foliar applications, the plants should first be cut to the ground and the re-sprouting foliage sprayed about 1 month later. Foliage of honeysuckle can also be sprayed in the fall or early spring when other species are dormant.

Biological: Currently there are no biological controls for Asian bittersweet or Japanese honeysuckle, although animal grazing may control the spread of Japanese honeysuckle.

ADDITIONAL INFORMATION SOURCES:

Dreyer, G. 1994. Element Stewardship Abstract for Asiatic and Oriental Bittersweet. The Nature Conservancy.

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Invasive Exotic Pest Plants in Tennessee. Tennessee Exotic Pest Plant Council.

Nuzzo, V. 1997. Element Stewardship Abstract for Japanese Honeysuckle. The Nature Conservancy.

Virginia Native Plant Society. 1995. Invasive Alien Plant Species of Virginia: Oriental Bittersweet (*Celastrus orbiculatus*).

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FS9JJ

INVASIVE PLANTS OF OHIO

Fact Sheet 10

Japanese Knotweed

Polygonum cuspidatum

Division Photo

DESCRIPTION:

Japanese knotweed is a non-native, semi-woody perennial that grows in large clumps reaching heights of 3-10 feet. The stout, hollow stems are reddish brown and the nodes are swollen giving them a bamboo-like appearance. Typical of the smartweed family, nodes are enclosed by a modified leaf-life structure. Stems die back in the winter and new ones are produced each spring. Leaves are alternate and egg-shaped (4-6 inches long and 3-4 inches wide) narrowing to a point at the tip. The tiny (1/8 inch) flowers are creamy white to greenish white and are borne in plume-like clusters in the upper leaf axils. The species is dioecious, producing male and female flowers on separate plants, however male plants are rare. Flowers bloom in August - September and female plants produce triangular, shiny black fruits, however, reproduction from seed is infrequent. This plant spreads primarily by its extensive rhizomes creating dense thickets.

HABITAT:

The species occupies a wide variety of habitats in many soil types and a range of moisture conditions. It is most common along roadsides and on streambanks, but is also found in low-lying areas, utility rights-of-way, old home sites and along woodland edges and openings. The species requires a high light environment and grows poorly under full forest canopies.

DISTRIBUTION:

Japanese knotweed was introduced from Asia as an ornamental in the late 19th century because of its unusual bamboo-like growth habit. It has been used as a landscape screening and occasionally for erosion control. It is widely distributed in the U.S., occurring in much of the Midwest and in several western states. In Ohio this species is primarily found in the eastern part of the state.

Jim Stahl

PROBLEM:

Japanese knotweed grows quickly and aggressively by extensive rhizomes and forms dense thickets that exclude native vegetation and reduce wildlife habitat. This species represents a significant threat to riparian areas where it can spread easily as small

pieces of rhizome are washed downstream and deposited to create new colonies. Transfer of soil containing rhizome or seed may also cause the establishment of new colonies. Establishment can be prevented with careful monitoring and eradication of small patches when they first develop.

CONTROL:

Mechanical: Large colonies of this species are extremely difficult to dig up due to their high rhizome densities. Digging of large colonies is not recommended as it is very labor intensive and unlikely that all below ground material can be removed. Small patches may be dug, however care should be used in removing plant material as improper disposal can spread the species further. Repetitive cutting or mowing within a single growing season to deplete stored reserves and remove photosynthetic tissue has been effective. Eradication of the rhizome system is necessary for control of this aggressive invasive species.

Chemical: Herbicide has been generally effective at controlling this species. Repetitive cutting of stems with spot application of Roundup®, Accord® or Glypro® to the stumps, and foliar spraying in large populations has been reported to be successful.

Biological: There are currently no biological controls available for Japanese knotweed.

ADDITIONAL INFORMATION SOURCES:

Seiger, L.A. 1999. Element Stewardship Abstract for *Polygonum cuspidatum*. The Nature Conservancy.

Seiger, L.A. and H.C. Merchant. 1997. Mechanical control of Japanese knotweed (*Fallopia japonica* [Houtt.] Ronse Decraene): effects of cutting regime on rhizomatous reserves. Natural Areas Journal 17(4): 341-345.

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FS10KC

INVASIVE PLANTS OF OHIO

Fact Sheet 11

Narrow-leaved and Hybrid Cattail

Typha angustifolia, T. Xglauca

DESCRIPTION:

Narrow-leaved cattail is a non-native, invasive plant that hybridizes with the native broad-leaved cattail (*T. latifolia*) to produce the invasive *T.* x*glauca*. All three aquatic perennials may grow up to a height of 10 feet and produce a velvety brown spike of flowers. The flower head of the hybrid and the narrow-leaved cattail have a gap of 1-4 inches between the male and female flowers, while the native species has both flower types next to each other. The leaves of cattail originate from the base and spread outward. The narrow-leaved and hybrid cattails have leaves that are ¼ -¾ inch across; the native cattail's leaves are wider at ½ -1 inch. A starchy rhizome forms beneath each plant.

Narrow-leaved (Left) and Broad-leaved (Right) Cattail Division Photo

HABITAT:

Stands of cattail can be found in a wide variety of wetland habitats, including marshes, lakeshores, river backwaters and roadside ditches. This prolific plant can grow in disturbed areas, as well as brackish, and polluted waters of depths nearing 3 feet.

Cattail infestation Division Photo

DISTRIBUTION:

Narrow-leaved cattails are believed to have been introduced to the Atlantic seaboard from the dry ballast of European ships. This plant has since spread westward and occurs throughout much of the United States. The hybrid cattail is concentrated in the northeast, but may occur wherever both the native and the narrow-leaved species are present. All three taxa are found throughout Ohio.

PROBLEM:

Narrow-leaved and hybrid cattail will out-compete native plants in wetland systems. These plants establish dense monocultures that enable them to shade out native vegetation. They are also thought to be allelopathic, producing chemicals which discourage growth of other plant species. Cattails reproduce both vegetatively by rhizomes and sexually through massive amounts of seed.

CONTROL:

Mechanical: Manipulation of water levels can kill cattails by inhibiting airflow from the cattail shoots to the roots. Removing the dead leaves and submerging the shoots in early spring will eliminate gas diffusion and "suffocate" the plant. In situations where water level manipulations are either not feasible or appropriate, pulling, cutting and bulldozing treatments have been used with some success. In the case of bulldozing, the benefits in effective removal may not outweigh the costs of disturbing the wetland.

Chemical: Wick and foliar applications of systemic herbicides such as Accord®, Rodeo® or Glypro® followed by manual clipping and removal of stems can be successful. Re-treatments are usually necessary due to the extensive root system.

Biological: Currently there are no biological control methods for cattails.

ADDITIONAL INFORMATION SOURCES:

Hoffman, R. and K. Kearns, eds. 1997. Wisconsin Manual of Control Recommendations for Ecologically Invasive Plants. Bureau of Endangered Resources, Wisconsin Department of Natural Resources.

Grace, J.B. and J.S. Harrison. 1986. The Biology of Canadian Weeds: *Typha latifolia* L., *T. angustifolia* L. and *T.* x*glauca* Godr. Canadian Journal of Plant Science 66: 361-379.

Motivans, K. and S. Apfelbaum. 1987. Element Stewardship Abstract for *Typha* spp. The Nature Conservancy.

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INVASIVE PLANTS OF OHIO

Fact Sheet 12

Eurasian Water-Milfoil

Myriophyllum spicatum

DESCRIPTION:

Eurasian water-milfoil is a non-native rooted aquatic plant with long stems that branch near the water's surface to create a canopy of floating foliage. The leaves are in whorls of four with 14-20 pairs of feathery leaf divisions. A spike of pink flowers emerges above the water and then falls horizontally when in fruit. Eurasian water-milfoil closely resembles the native northern water-milfoil (*M. exalbescens*). A reliable distinguishing characteristic is the number of leaf divisions; northern water-milfoil has fewer (5-12) than the non-native species.

HABITAT:

Eurasian water-milfoil can grow in a variety of aquatic habitats, but prefers fertile, fine-textured inorganic sediments. It is an opportunistic species that invades disturbed lake beds, recreational waterways and slow moving streams. Optimal growth occurs in alkaline systems with high concentrations of dissolved inorganic carbon.

DISTRIBUTION:

Native to Europe, Asia and northern Africa this plant was introduced to the United States by the aquarium industry. It has been spread both purposefully by fishermen who introduced it to lakes for fish habitat and accidentally when caught in boat propellers and carried to a new body of water. In the last five decades it has spread throughout much of North America from Florida to Quebec in the east, and California to British Columbia in the west. Eurasian water-milfoil was first found in Ohio in 1950 and is now common throughout the state.

C. Barre Hellquist - North Adams State College, Massachusetts

PROBLEM:

Dense canopies of Eurasian water-milfoil shade out native vegetation, alter the species composition of aquatic inverte-brates and may impair the ability of some fish species to spawn. As an opportunistic species, this plant starts growing early in the spring and is capable of rapid dispersion through fragmentation of plant parts. Each fragment is able to grow roots and develop into a new plant. Due to the plant's ability to form dense growths, water recreation activities such as swimming, boating and fishing are inhibited.

CONTROL:

Mechanical: Mechanical cutters and harvesters, as well as hand-pulling, are the most common methods of Eurasian water-milfoil control. To be effective, all fragments must be collected and removed from the site to eliminate new establishments. Manipulations of the water level, where feasible, may have an effect on the plant. Low water levels can desiccate populations and high levels will "drown" the plants by not giving them access to enough light.

Chemical: Fluridone® is a selective aquatic herbicide for Eurasian water-milfoil and other aquatic weeds that may be useful.

Biological: A native weevil (*Eurhychipsis lecontei*) has been found to feed and reproduce on Eurasian water-milfoil. This insect may be an excellent control method in that it is selective to this species and does not appear to feed on native water-milfoils. Other biological control methods including a fungus (*Mycoleptidiscus terrestris*) are currently being researched.

ADDITIONAL INFORMATION SOURCES:

Boylen, C.W., L.W. Eichler and J.D. Madsen. 1999. Loss of native aquatic plant species in a community dominated by Eurasian water-milfoil. Hydrobiologia 415: 207-211.

Hoffman, R. and K. Kearns, eds. 1997. Wisconsin Manual of Control Recommendations for Ecologically Invasive Plants. Bureau of Endangered Resources, Wisconsin Department of Natural Resources.

Sheldon, S.P. and R.P. Creed. 1995. Use of a native insect as a biological control for an introduced weed. Ecological Applications 5(4): 1127-1132.

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INVASIVE PLANTS OF OHIO

Fact Sheet 13

Smooth Brome

Bromus inermis

DESCRIPTION:

Division Photo

Smooth brome, also known as Hungarian brome, is a non-native, long-lived, herbaceous perennial. This cool-season grass can grow nearly 4 feet tall. Emerging in late March, the numerous basal and stem leaves are smooth, under ½ inch wide and up to 8 inches long. Each leaf has a characteristic "W" shaped wrinkle near its tip. From May to July, a nearly smooth stem supports the flowering portion of the plant. The flower heads are characterized by having 4-10 upright branching-spikes. Each spike is 1-2 inches long and comprised of up to 10 blunt tipped florets. The florets take on a purple-brown color as they mature from June to August and begin to set seed. Reproduction is both by seed and by its aggressive rhizomes.

HABITAT:

Smooth brome grows well in open areas such as roadsides, riverbanks, open fields and woodland edges. It is drought resistant and may go dormant during harsh conditions. It is also tolerant of periodic flooding. Open areas such as prairies, savannas, and meadows are extremely susceptible to invasion by smooth brome.

Division Photo

DISTRIBUTION:

Smooth brome was introduced to the United States from Europe and eastern Asia in 1884. It was, and still is, used as a forage crop for livestock and for erosion control along streams. It is found throughout the United States except for the extreme southeast. It is found throughout Ohio. It is most common in agricultural areas where it has escaped from its intended use.

PROBLEM:

Because of the early season growth and aggressive spread of smooth brome, it can out-compete many of the warm-season native plants found in prairies and grasslands for water and nutrients. The sod-forming roots of established smooth brome populations can prevent other species from emerging. Seeds may stay viable for up to 10 years, which coupled with its tenacious growth, makes this grass species difficult to eradicate.

CONTROL:

Mechanical: Prescribed burning after shoots emerge in late spring can help control the spread of smooth brome. This also helps favor native warm-season species of plants. However, early burning may favor the growth of smooth brome. Continual mowing can also be effective, but this normally affects non-target species as well. Control should be undertaken to prevent seed production.

Chemical: A systemic herbicide such as Roundup® or Glypro®, or a grass-specific herbicide such as Fusilade DX® can be effectively applied to dense populations in April or May. Care must be taken to avoid non-target species.

Biological: Currently there are no biological controls for smooth brome.

ADDITIONAL INFORMATION SOURCES:

Sather, N. 1987. Element Stewardship Abstract for Awnless Brome, Smooth Brome. The Nature Conservancy.

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FS13JJ

INVASIVE PLANTS OF OHIO

Fact Sheet 14

Canada Thistle

Cirsium arvense

Division Photo

DESCRIPTION:

Canada thistle is a slender, herbaceous, non-native perennial plant reaching a height of 2-4 feet. The leaves are simple, alternate, irregularly lobed, and taper towards the tip. The underside of the leaf is normally smooth with the margin bearing many sharp spines. Stems are grooved, hairy, and branched at the top. The root system is comprised of a deep taproot that may extend 6 feet down and an extensive creeping rhizome that other thistles in Ohio lack. Numerous fragrant, lavender-pink, one-inch flowers adorn the plant from June to September. A single plant may produce up to 5,300 seeds, each of which is attached to a hair-like tuft making them easily dispersed by the wind.

HABITAT:

Canada thistle occurs in nearly every open habitat within its range and tolerates nearly any soil type that is not waterlogged. In natural areas, it is a particular problem in old fields, prairies, savannas, and early successional forests. It can also be a problem in wet sedge meadows where it invades areas above the waterline.

DISTRIBUTION:

Despite its name, Canada thistle is not native to Canada or even to North America. It is native to eastern and northern Europe and western Asia, and was introduced to North America in the 1600s. It has spread throughout all of the United States except the southeast. It is found throughout Ohio.

PROBLEM:

The extensive root system of Canada thistle allows it to out-compete and displace many native species, especially in degraded prairies where native species are not well established. Spreading both by seed and rhizome, Canada thistle can create monocultures covering large areas. The wind-dispersed seeds may remain viable for 20 years or more, allowing it to spread quickly and making it difficult to eradicate.

Division Photo

CONTROL:

Mechanical: Prescribed burning, especially in the spring, can be effective by reducing thistle density and allowing native species to compete for resources. Mowing will temporarily reduce the amount of Canada thistle, but will not kill it unless mowing is repeated often for many years - which can also harm native plants as well. Hand pulling is usually ineffective since small portions of broken taproot can easily regenerate.

Chemical: Foliar spraying of a systemic herbicide such as Roundup®, Glypro®, or Transline® is an effective control method. Fall and spring are normally the best times to treat Canada thistle to maximize the herbicide absorption into the deep taproot. Several applications will usually be needed.

Biological: There are currently no effective biological controls for Canada thistle.

ADDITIONAL INFORMATION SOURCES:

Doll, J.D. 1997. Controlling Canada Thistle. North Central Regional Extension. Publication No. 218.

Evans, J. E. 1984. Canada Thistle (*Cirsium arvense*): a literature review of management practices. Natural Areas Journal 4(2): 11-21.

Nuzzo, V. 1987. Element Stewardship Abstract for Canada Thistle. The Nature Conservancy.

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FS14JJ

INVASIVE PLANTS OF OHIO

Fact Sheet 15

Common and Cut-leaved Teasel

Dipsaxus fullonum (sylvestris), D. laciniatus

DESCRIPTION:

Teasels are non-native biennials or short-lived perennials, that grow as a rosette for a minimum of one year, send up a tall flowering stalk and then die after setting seed. During the rosette stage teasels develop a large taproot that may be over two feet in length and an inch in diameter. When flowering, teasels can reach a height of 7 feet. Both species have flowers packed in a dense oval shaped inflorescence on top of a spiny stem. Common teasel has pink or purple flowers, undivided leaves and bracts that are longer than the flowering head. Cut-leaved teasel has deeply lobed leaves and white flowers. A single teasel plant can produce approximately 3,000 seeds.

Common Teasel Division Photo

Cut-leaved Teasel Division Photo

HABITAT:

Teasels thrive in open sunny conditions in mesic to dry habitats. Cut-leaved teasel is often found in wetter soils than common teasel; both tolerate saline conditions. Teasels are commonly found in abandoned fields, along roadsides and in cemeteries. They can invade prairies, savannas, sedge meadows and moist forest openings.

DISTRIBUTION:

Teasels are native to Eurasia and northern Africa. Introductions were probably made by early settlers deliberately as ornamentals or accidentally as toys made from the flowering heads. Teasels were also used commercially for combing wool. Common teasel is distributed throughout the United States (excluding the far north central states). Cut-leaved teasel currently has a more restricted range, primarily occurring in the northeastern and Midwestern states. Both species are found throughout Ohio, although common teasel is more abundant.

PROBLEM:

Teasels produce massive amounts of seed that can remain viable in the soil for several years and have germination rates as high as 86%. In addition, the death of a mother plant leaves behind an excellent “nursery” for new seedling establishment leading to a continuous population of dense monocultures. The combination of these life history traits enable teasels to successfully out-compete native plants.

CONTROL:

Mechanical: Individual rosettes can be removed using a dandelion digger; removal of the entire root is essential to eliminate re-sprouting. Flowering stalks may be cut down once the plant has initiated flowering, but if cut too soon plants may send up new flowering stalks. It has been shown that seeds will continue to develop and mature even after cutting. To prevent seed dispersal, the cut stalks should be removed.

Chemical: Foliar application of herbicides is effective and useful when mechanical treatments are not feasible. Herbicide, such as Roundup®, Glypro®, or Transline® should be applied to the rosette stage. In natural areas, application during the late fall or early spring will result in less harm to non-targeted species.

Biological: No biological control methods are currently available.

Teasel in Fruit Division Photo

ADDITIONAL INFORMATION SOURCES:

Huenneke, L.F. and J.K. Thomson. 1995. Potential interference between a threatened endemic thistle and an invasive nonnative plant. Conservation Biology 9(2): 416-425.

Solecki, M.K. 1991. Cut-leaved and common teasel: profile of two invasive aliens. Biological Pollution: The Control and Impact of Invasive Exotic Species. Indiana Academy of Science, Indianapolis, Indiana, USA.

Werner, P.A. 1975. The Biology of Canadian Weeds: *Dipsacus sylvestris*. Canadian Journal of Plant Science 55: 783-4.

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FS15SS

INVASIVE PLANTS OF OHIO

Fact Sheet 17

Tree-of-Heaven

Ailanthus altissima

DESCRIPTION:

Tree-of-heaven is a rapidly growing non-native tree that reaches a maximum height of about 80 feet. The bark is gray to brownish-gray, often turning nearly black with age. Twigs and stems range from light to dark brown. The leaves are pinnately compound with 11-41 leaflets. Each leaflet has an entire margin except for 1-5 small gland-tipped teeth near its base. In late spring, tree-of-heaven produces dense clusters of small, 5-6 petaled, yellow-green flowers near the ends of the upper branches. Seeds develop in the fall and may remain on the tree throughout the winter. Each seed is borne in the middle of a twisted, flattened, wing-like structure. The wood is light in color and weak, rotting quickly when dead. Leaves and young stems have an unpleasant odor that resembles rancid peanut butter. Care should be taken in identification to avoid confusing tree-of-heaven with native species such as walnut and sumac.

Division Photo

HABITAT:

Tree-of-heaven can be found in nearly any habitat except wetlands. It thrives in disturbed soils in both urban and natural areas. In natural areas, tree-of-heaven invades fencerows, roadsides, woodland edges, successional forests, and open forest thickets. Tree-of-heaven thrives in poor soils and tolerates pollution well, a reason why it is often planted in urban areas.

DISTRIBUTION:

Tree-of-heaven was introduced to the United States from China. It was first brought to Philadelphia as a garden plant in 1784. By the mid 1800's, it was well established as a nursery tree because of its ability to grow nearly anywhere. Chinese immigrants that came to the United States to work in the gold mines also introduced it to California as a medicinal plant. Absent only from the northern plains of the United States, tree-of-heaven is found throughout Ohio. It poses the greatest threat to successional forest areas of Ohio.

PROBLEM:

One mature tree-of-heaven can produce up to 350,000 seeds per year. These seeds are easily airborne and can be transported by water and birds as well. Germination of seeds is quite high. Mature trees also reproduce extensively by sending up root suckers and sprouts from cut stumps. Sapling growth can reach 3-4 feet a year and can outgrow nearly any native tree, out-competing natives for light. The roots give off a toxin that acts as a herbicide that can kill or inhibit the growth of other plants. Tree-of-heaven is somewhat shade-tolerant and can grow quickly when released by gaps in the forest canopy caused by windfalls, logging or defoliation due to insect pests such as gypsy moth.

Tree-of-Heaven in the understory Division Photo

CONTROL:

Mechanical: Young seedlings may be successfully hand-pulled if the entire root system is removed. If small portions of the root system are left, regeneration is likely. Cutting alone is usually not effective since this merely stimulates aggressive root suckering and stump sprouting. However, cutting large trees can help control its spread by removing seed-producing trees.

Chemical: It is of utmost importance to kill the entire root system. Systemic herbicides such as Roundup® or Glypro® may be effective as a foliar spray on seedlings. For larger trees, cut stump treatment or basal bark application using a systemic herbicide such as Garlon 4® is best especially if treated in late winter or late summer. Using a small amount of Tordon K® with the Garlon 4® mixture will increase success of basal bark or cut stump application, but care must be used as Tordon K® can translocate from the root system of the target tree and kill non-target plants.

Biological: No biological controls are currently available.

ADDITIONAL INFORMATION SOURCES:

Hoshovsky, M. 1999. Element Stewardship Abstract for Tree-of-Heaven. The Nature Conservancy.

Bartlow, J., K. Johnson, M. Kertis, T. Remaley, S. Ross, E. Simet, T. Smith, D. Soehn and G.Taylor. 1996. Invasive Exotic Pest Plants in Tennessee. Tennessee Exotic Pest Plant Council.

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INVASIVE PLANTS OF OHIO

Fact Sheet 16

White and Yellow Sweet-clover

Melilotus alba, M. officinalis

Yellow Sweet-clover Division Photo

DESCRIPTION:

Both white and yellow sweet-clover are erect, herbaceous, non-native biennials that are members of the pea family. In their first year of growth, the plants are small with a smooth multi-branched stem. The leaves are alternate and divided into 3 finely toothed leaflets. The second year of growth is characterized by rapid growth of the root system and an overall bushy appearance with the plant reaching 3-5 feet tall by May. From May to September, flowers are produced on the second year plants. Flowers are borne on irregular spikes on the ends of elongated stems. Each flower spike will bear 40-80 flowers. The flowers are either white or yellow, the most obvious difference between these two species. Seed is set in summer with up to 350,000 seeds per plant.

HABITAT:

White and yellow sweet-clovers grow in open, disturbed areas such as roadsides, old fields, and utility easements. Intolerant of shade, sweet-clover invades upland habitats such as prairies, savannas, dunes, alvars, and meadows. They seem to grow best in, but are not limited to, calcareous soil. The roots of sweet-clover fix nitrogen in the soil, allowing the plants to live in nutrient poor areas.

DISTRIBUTION:

White and yellow sweet-clover are native to the Mediterranean region, central Europe, and Asia. They were brought to the United States in the 1600s as a forage crop for livestock and for honey production. They are now found in all 50 states and are used as a soil builder because of their nitrogen fixing capability. They are also often planted as wildlife cover. Both sweet-clovers are found throughout Ohio especially near agricultural regions.

PROBLEM:

The seeds of white and yellow sweet-clover have been shown to be viable for over 30 years. The plants are drought resistant and winter hardy. Because of their large size in the second year of growth, they tend to overtop and shade native sun-loving species. They are problematic in recovering prairies and savannas where they out-compete native species for water and nutrients.

White Sweet-clover Division Photo

CONTROL:

Mechanical: Prescribed burning in 2 or more consecutive years has been effective in reducing populations of white and yellow sweet-clover. However, burning in only 1 year tends to increase populations. In small areas, hand pulling of first year plants when roots are small is also quite effective.

Chemical: Spraying with systemic herbicides such as Roundup® or Glypro® can be effective. Care must be taken to prevent over-spray to non-target species.

Biological: The native sweet-clover weevil can help control white and yellow sweet-clover if the weevil is present in high concentrations. Unfortunately, this is not a reliable form of control.

ADDITIONAL INFORMATION SOURCES:

Eckardt, N. 1987. Element Stewardship Abstract for White and Yellow Sweetclover. The Nature Conservancy.

Turkington, R.A., P.B. Cavers, and E. Rempel. 1978. The Biology of Canadian Weeds: *Melilotus alba* Desr. and *M. officinalis* (L.) Lam. Canadian Journal of Plant Science 58: 523-537.

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INVASIVE PLANTS OF OHIO

Fact Sheet 18

Lesser Naiad and Curly Pondweed

Najas minor, Potamogeton crispus

Lesser Naiad C. Barre Hellquist

DESCRIPTION:

Lesser naiad is a non-native, small, branching aquatic annual with coarsely toothed leaves. The flowers are small, occurring in clusters along the leaf axils. Curly pondweed is a non-native submerged aquatic plant with oblong leaves alternately placed on the stem. Leaf margins are wavy and have minute teeth along their entire length. There are no floating leaves, but a spike of terminal flowers rises above the water.

HABITAT:

Lesser naiad is most common in rivers and alkaline lakes. Curly pondweed grows in fresh and brackish streams and ponds. Both species often occur with other non-native invasive species, such as Eurasian water-milfoil (*Myriophyllum spicatum*).

DISTRIBUTION:

Lesser naiad is native to Europe and Asia. It has been speculated that seeds or plant parts were brought here accidentally on ships. Curly pondweed was introduced from Europe over 150 years ago and its increasing distribution may be due to migrating water birds. Both plants are common throughout the United States and are widely distributed in Ohio.

Curly Pondweed C. Barre Hellquist - North Adams State College, MA

PROBLEM:

Once established, both lesser naiad and curly pondweed can be aggressive weeds. These plants grow profusely early in the season, often shading out and inhibiting the growth of native plants.

CONTROL:

Mechanical: Manual removal of lesser naiad may prove to be difficult due to the brittle nature of the plant. Avoid fragmenting the plants and remove all stems for effective control.

Chemical: Herbicides such as Cutrine®, Weedtrine®, Aquathol K® and Diquat® can be used to effectively kill curly pondweed and lesser naiad.

Biological: No known biological control methods are currently available.

ADDITIONAL INFORMATION SOURCES:

Borman, S. 1997. A field guild to aquatic plants. Wisconsin Lakes Partnership.

Schmidt, J.C. 1987. How to identify and control water weeds and algae. Applied Biochemists, Inc.

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